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Report on

A PRELIMINARY STUDY OF WINTER WEATHER CONDITIONS ON THE CLARKS FORK ROAD

prepared for

The Wyoming Highway Department

by

Ronald D. Tabler
Rocky Mountain Forest & Range
Experiment Station
Forest Service, USDA

June 15, 1972

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
Rocky Mountain Forest and Range Experiment Station
240 West Prospect Street
Fort Collins, Colorado 80521

4040(4300)
June 15, 1972

Mr. William G. Lucas
Superintendent and Chief Engineer
Wyoming Highway Department
P. O. Box 1708
Cheyenne, Wyoming 82001

Dear Mr. Lucas:

Enclosed is the "Report on a preliminary study of winter weather conditions on the Clarks Fork Road", prepared by Dr. Ronald D. Tabler, Principal Research Hydrologist, at our laboratory in Laramie. This report results from your request of June 2, 1971, for Dr. Tabler to participate in the environmental study of the Clarks Fork Canyon area.

We are grateful for the opportunity to contribute to this effort, and trust you will find the information of value.

Sincerely,

Karl F. Wenger

KARL F. WENGER
Director

Enclosure

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Report on

A PRELIMINARY STUDY OF WINTER WEATHER CONDITIONS ON THE CLARKS FORK ROAD

Prepared for

THE WYOMING HIGHWAY DEPARTMENT

by

Ronald D. Tabler

Principal Research Hydrologist

Rocky Mountain Forest and Range Experiment Station

Forest Service, USDA

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INTRODUCTION

The Wyoming Highway Department is presently studying alternative routes for the final 37 miles of the Clarks Fork Road (Wyoming 296), linking US 212 to Wyoming 120 north of Cody. Of the 47-mile total distance between these two highways, construction has been completed on the first 5 miles south of US 212, and construction is in progress on an adjoining 4 miles. This first 9 miles is essentially a reconstruction of the existing Sunlight Basin road, with only minor alignment adjustments. Of the several alternative routes that have been considered for the east end of the Clarks Fork corridor, the two choices receiving most attention are the "Summit" route, following the existing Sunlight Basin road over Dead Indian Pass, and the "Canyon" route, which would be a new location nearer the Clarks Fork River, eventually descending down the south wall of the Clarks Fork Canyon (Fig. 1).

An obvious advantage of a canyon route is that it would avoid the blowing and drifting snow conditions that prevail on 8,000-ft Dead Indian Pass during the winter. The elevation and grade advantages are obvious in the comparative profiles shown in Figure 2. Because a completed (paved) road extends about 11 miles west of Wyoming 120 to the mouth of the Clarks Fork Canyon, the canyon route would save about 15 miles of additional construction.

The principal advantage of the summit route, according to its proponents, is that it would have less esthetic impact and preserve the unspoiled beauty of the canyon.

In response to public concern about the corridor location, the Wyoming Highway Department has assembled a team of consultants to conduct an environmental study of alternatives. As part of that study, this report summarizes results from an exploratory investigation during the 1971-72 winter to supplement existing information on winter weather conditions in the Clarks Fork - Dead Indian Hill area. The study reported herein was undertaken by the Wyoming Highway Department, in consultation with the author, who analyzed and interpreted the data.

THE STUDY

Objectives.--Although some information is available concerning precipitation patterns and temperatures in the Clarks Fork - Dead Indian Hill area, little is known about the winds, except that they are reputed to be exceptionally strong. Because wind conditions might have a bearing on corridor location, a primary objective was to compare winter winds at Dead Indian Pass with those in the lower reaches of Clarks Fork Canyon. Variables of particular interest included hourly and daily mean windspeeds, wind direction, and gustiness.

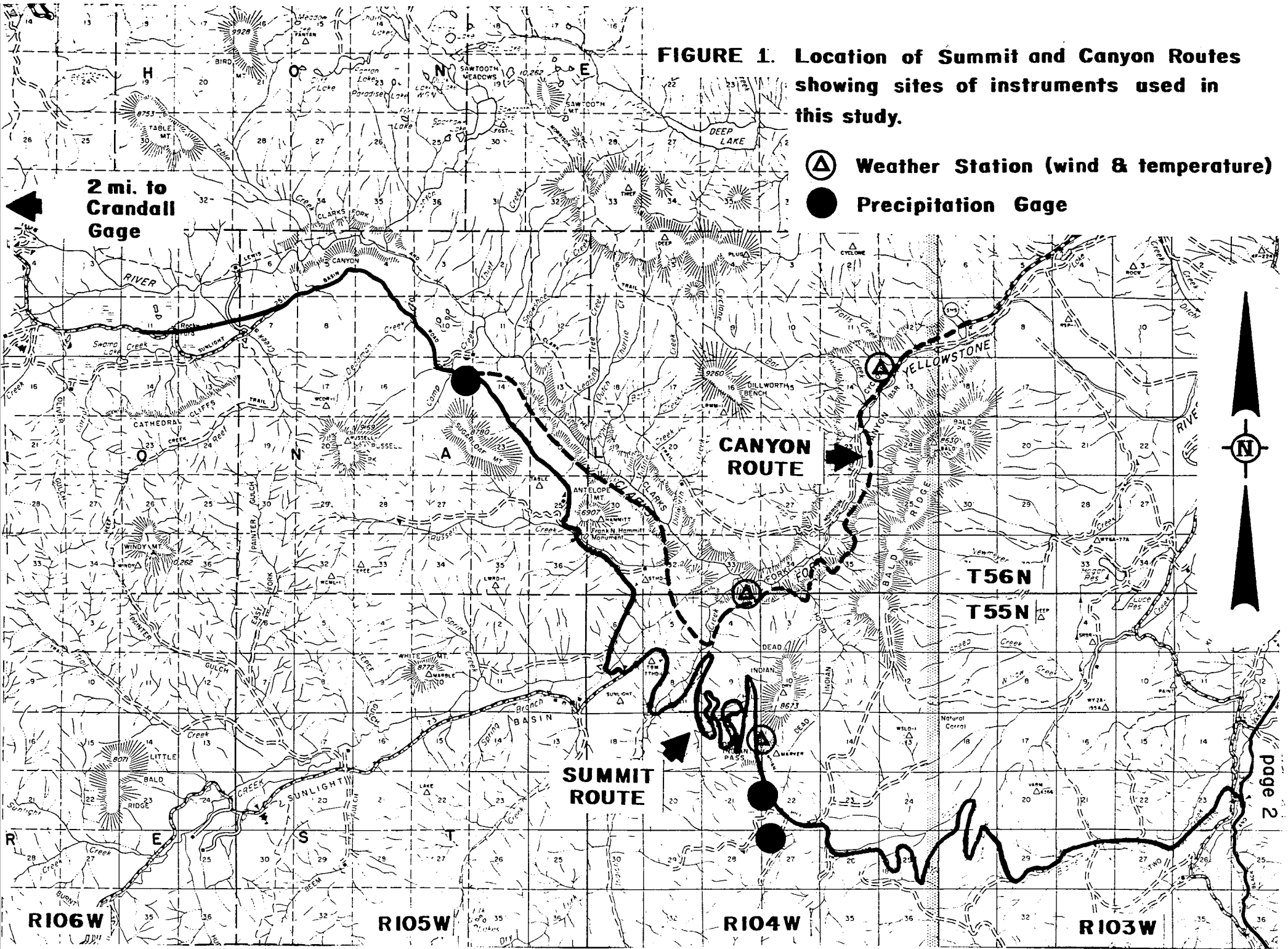


FIGURE 1. Location of Summit and Canyon Routes showing sites of instruments used in this study.

Weather Station (wind & temperature)

Precipitation Gage

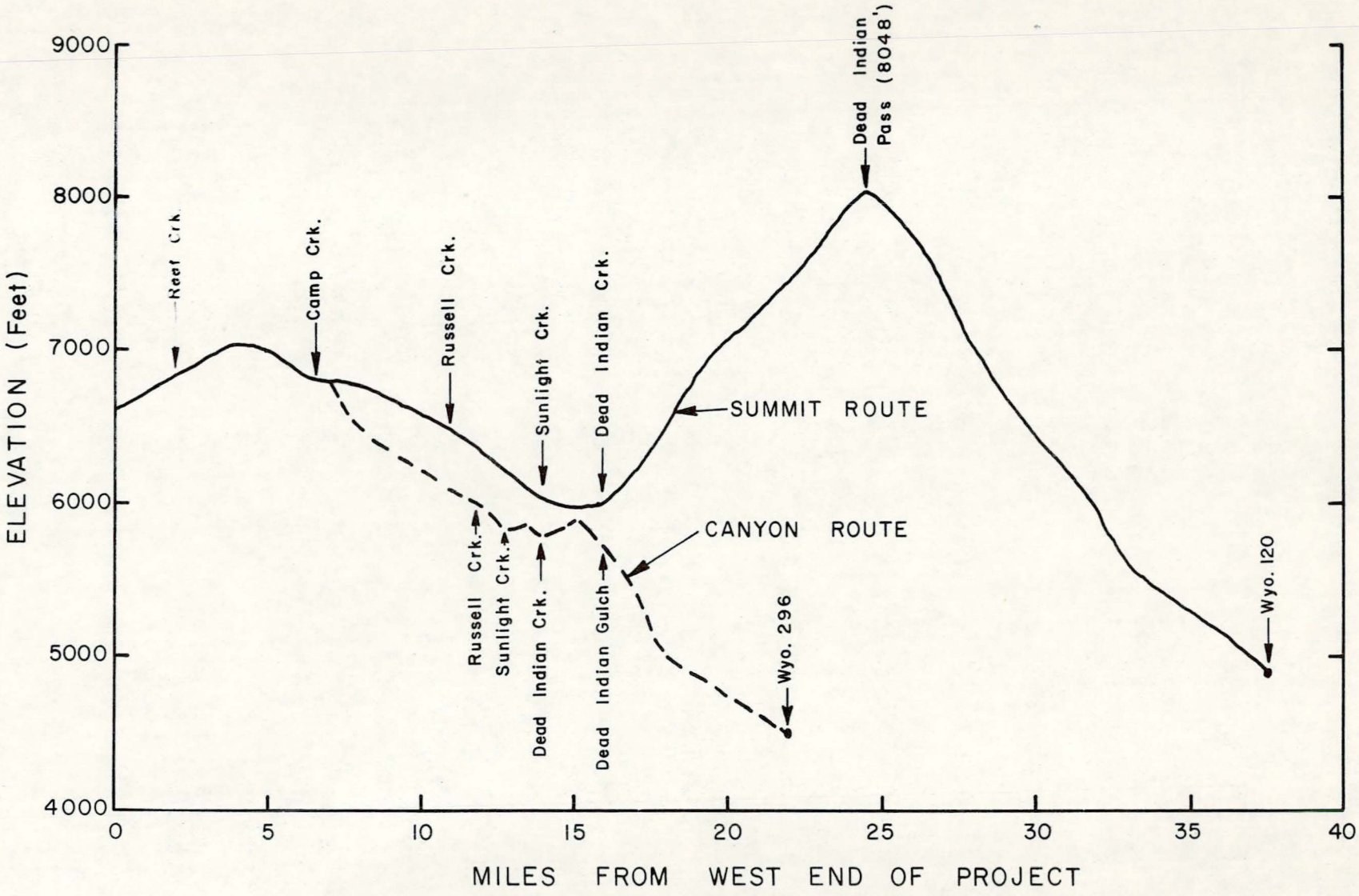


Figure 2.-- Approximate profiles of the Summit and Canyon routes.

A second objective was to gain additional information on the air temperature at these two locations, since this factor affects ice formation on road surfaces and also has an important bearing on snowdrift accumulation.

The third objective was to determine the precipitation on Dead Indian Hill during the 1971-72 winter, and relate this to the long-term record at the Crandall creek gage, located about 15 miles northwest from the summit. This information, together with the temperature data, allows estimation of the amount of snow fencing required on the summit route, which in turn should enhance economic assessment of alternative corridor locations.

Instrumentation.--A Meteorology Research, Inc. (MRI) Model 1071 weather station was installed at each of three sites (Fig. 1 and Table 1), with the anemometer cups at 2 meters above the ground. The "Summit" site was near Dead Indian Pass (Fig. 3), and the "Canyon" weather station was installed near Cyclone Bar, about 2 miles upstream from the canyon mouth (Fig. 4). The third station, at an intermediate elevation, was located on the canyon route about ½ mile downstream from where Dead Indian Creek empties into the Clarks Fork River (Fig. 5). This site was chosen to detect wind channeling down the Clarks Fork River or Sunlight Creek.

Table 1. Location of instruments

Name	Location	Elevation (feet)
. . . . . MRI Weather Stations		
Summit	SW¼NW¼ S15, T55N, R104W	8200
Gulch	NE¼NE¼ S4, T55N, R104W	5800
Canyon	NW¼NW¼ S13, T56N, R104W	4700
. . . . . Precipitation Gages		
Summit	SW¼NW¼ S22, T55N, R104W	8000
Dry Fork	SW¼NW¼ S27, T55N, R104W	7900
Camp Creek	NE¼ S15, T56N, R105W	6800

The MRI Model 1071 weather station is a battery-operated instrument that records accumulated wind-run, wind direction, and air temperature on a strip-chart (Fig. 6). Examples of the records appear later in this report.

Two storage type precipitation gages equipped with wind shields (Fig. 7) were installed in small forest openings on the east side of

Figure 3. Site of Dead Indian Pass ("Summit") Weather Station

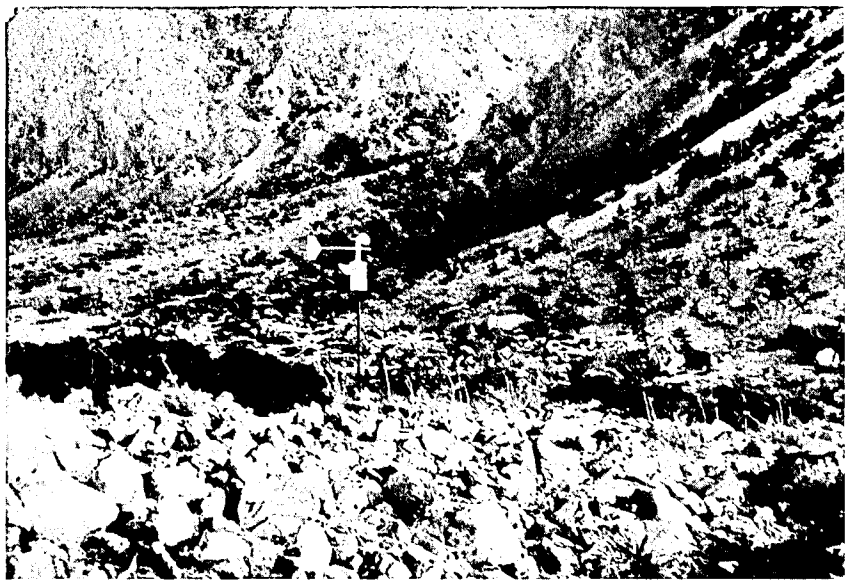


Figure 4. The Cyclone Bar ("Canyon") Weather Station

Figure 5. The Dead Indian Creek ("Gulch") Weather Station

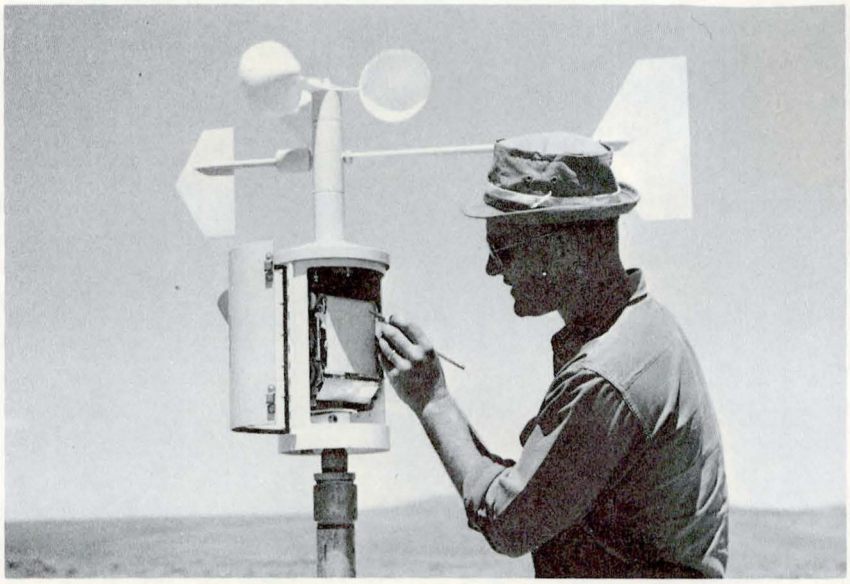


Figure 6. Weather Station (Meteorology Research, Inc., Model 1071) used to collect wind and temperature data for this study.

Figure 7. The Dry Fork precipitation gage located 2 miles south of Dead Indian Pass.

Dead Indian Pass. Data from a third gage near Camp Creek was used in the determination of snow control measures needed on the upper reach of the Clarks Fork road.

All instruments were installed in mid-November, 1971, and data were collected until May 1, 1972. Wyoming Highway Department personnel installed and serviced the instruments, and reduced the data. The author of this report consulted in the computer processing, analyzed the data, and interpreted the results.

Data sufficiency.--Although all three weather stations were operated from mid-November to May 1, several factors combined to result in the loss of a substantial amount of data. The 1971-72 winter was unusually severe, and Dead Indian Pass was closed to traffic for weeks at a time. This made access into the upper two weather stations impossible without over-snow vehicles. In addition, personnel servicing the instruments were unfamiliar with their operation, and were unable to cope with the mechanical challenge offered by the instruments.

Table 2 shows the amount of record obtained at each site, expressed in percent of the total possible for each month. Seasonal totals for the Canyon, Gulch, and Summit sites were 63, 25, and 33%, respectively.

Table 2. Usable record for each weather station expressed as percent of total possible

				concurrent data			
Month	Canyon	Gulch	Summit	Canyon/ Gulch	Canyon/ Summit	Gulch/ Summit	Canyon/ Gulch/ Summit
Nov.	51.4	13.1	25.4	13.1	13.5	3.6	3.6
Dec.	58.7	0	0	0	0	0	0
Jan.	71.8	37.2	28.8	37.2	28.8	28.8	28.8
Feb.	52.9	29.0	33.3	29.0	23.6	0	0
Mar.	75.7	70.6	16.3	67.3	16.3	16.3	16.3
Apr.	65.3	0	98.5	0	63.8	0	0
Total	62.8	25.1	33.4	24.6	24.2	8.3	8.3

This amount of data should suffice to define mean values and general features of the wind conditions at each site, but it is probable that maximum windspeeds during the winter exceeded the recorded maximums. Concurrent data for comparing Canyon/Gulch and Canyon/Summit pairs are available for about 25% of the winter, and this is probably sufficient to establish meaningful relationships

for these two pair-wise comparisons. Concurrent data for the Gulch/Summit comparison are available for only 8% of the winter, suggesting that this relationship would be best derived from a mathematical solution of the first two comparisons.

Data collected during the 1971-72 winter were not sufficient to adequately characterize air temperatures at the Summit or Gulch weather stations because of the interaction between unequal sampling during different months and the seasonal change in temperature. Using the Summit station as an example, Table 2 shows that the usable record for each of the 6 months beginning in November was 25, 0, 29, 33, 16, and 98%, respectively. Any estimate of the mean temperature for the winter would thus be biased by the 98% record in April and the complete absence of data in December. By comparison, the record from the Canyon site is distributed rather uniformly over the winter, providing a more representative picture of winter temperature conditions. Available concurrent record should suffice for meaningful comparisons between stations.

Precipitation data at the three sites were complete, providing an excellent sample of precipitation over the entire winter (November 1, 1971 to May 1, 1972).

WEATHER CONDITIONS

Windspeed.--The frequency distributions of mean hourly windspeeds at the three weather stations (Fig. 8) show that 50% of the recorded hourly values were less than 11, 14, and 16 mph at the Canyon, Gulch, and Summit sites, respectively. Although maximum recorded windspeeds (Table 3) were about the same for all sites, the summit had the strongest sustained winds, due to its exposed location on a ridge and convergence of the airflow as it passes over Dead Indian Hill.

Table 3. Maximum windspeeds recorded during the 1971-72 winter

Station	Mean windspeed (mph)	Date	Time
. . . . . Fastest hour			
Canyon	55	12/30/71	23-2400
Gulch	59	1/20/72	21-2200
Summit	65	11/19/71	01-0200
. . . . . Fastest 10 minutes			
Canyon	81	12/30/71	22-2300
Gulch	78	1/20/72	21-2200
Summit	78	11/19/71	01-0200

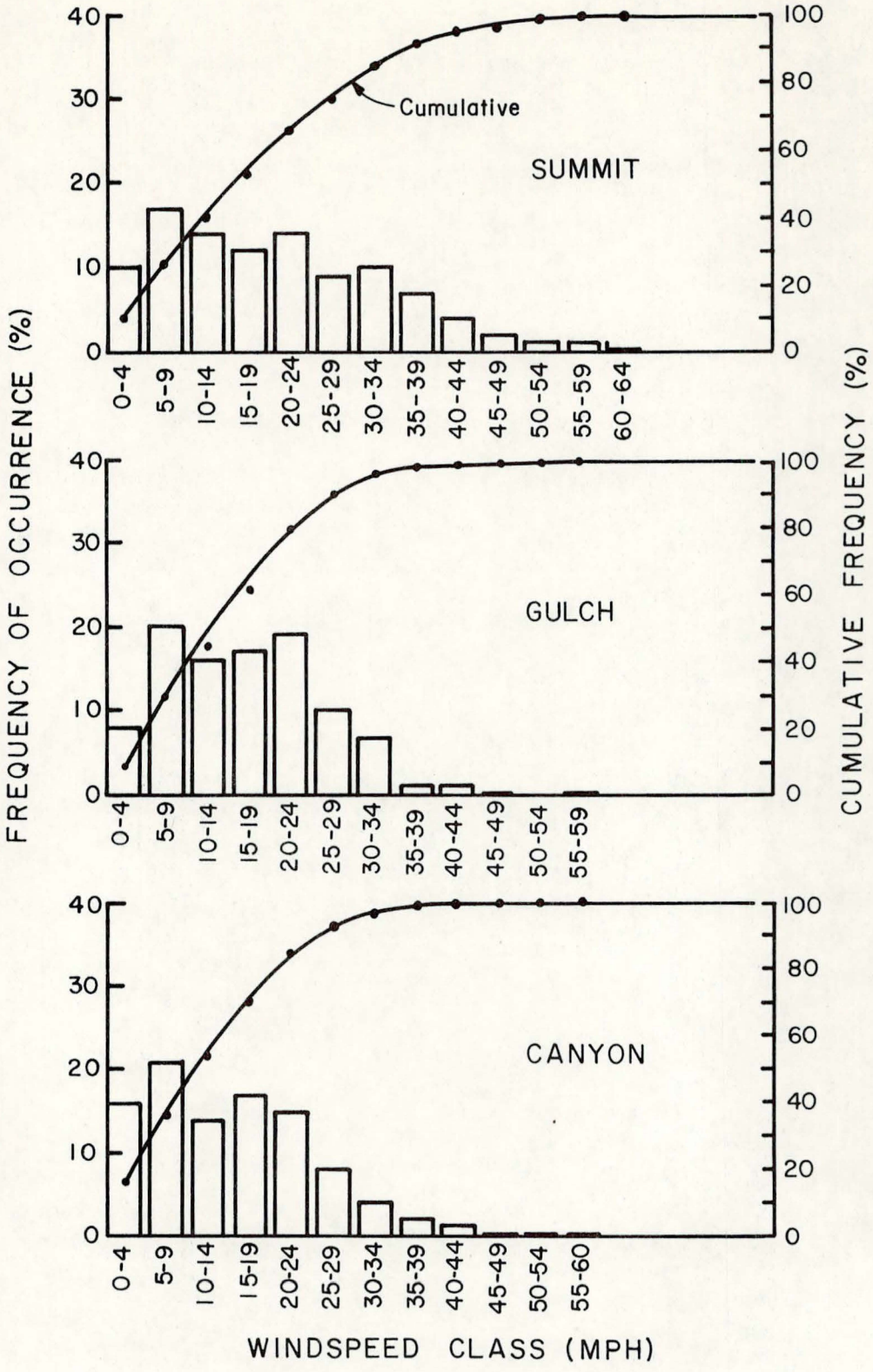


Figure 8. -- Frequency of mean hourly windspeeds at the three weather station sites (November 16, 1971 to May 1, 1972).

Strong winds at the summit are steady and relatively uniform over an hour's time, whereas winds are often gusty in the canyon--10-minute wind speeds during a single hour were observed to vary from 24 to 75 mph (12/31/71) during an hour averaging 48 mph. By comparison, the typical variation at the summit during a 50 mph average was 40 to 60 mph (1/24/72). The Gulch site was intermediate between these two extremes. Figure 9 shows concurrent records for the three sites during a wind storm on November 19.

Convergence of airflow is responsible for the strong winds in the canyon. Wind is funneled down the canyon, which acts as a pass between "Cyclone Ridge" (elevations up to 10,500 ft) and "Bald Ridge" (peak elevation 8,630). This channeling results in a deflection of almost 90° from the original westerly flow, generating the turbulence which gives Cyclone Bar its name. Funneling of wind down the canyon is substantiated by the fact that the mean wind direction for winds above 15 mph in the canyon is approximately due south, while the concurrent direction at the summit is approximately due west (see Fig. 9 for an example). The gusty, turbulent nature of the canyon wind has undoubtedly contributed to the canyon's reputation for strong winds. Because of the adverse effects of gusty winds on vehicle stability, this is an important factor to be considered in assessing the feasibility of the canyon route.

Significant correlations between stations were observed with respect to mean hourly and daily windspeeds (Table 4). There is

Table 4. Correlations between mean windspeeds (mph) at the three weather stations

Comparison	Equation	Correlation coefficient(r)	N	Standard error($S_{\hat{y}}$)
. . . . .	mean hourly windspeeds	. . . . .		
Canyon(U_c)/Summit(U_s)	$U_c = 5 + 0.4U_s$	0.63	1056	0.21
Canyon(U_c)/Gulch(U_g)	$U_c = 7 + 0.5U_s$	0.56	1074	0.21
Gulch (U_g)/Summit(U_s)	$U_g = -4 + 0.8U_s$	(mathematical derivation)		
. . . . .	mean daily windspeeds	. . . . .		
Canyon(U_c)/Summit(U_s)	$U_c = 3 + 0.5U_s$	0.83	49	0.58
Canyon(U_c)/Gulch(U_g)	$U_c = 4 + 0.6U_g$	0.81	48	0.49
Gulch (U_g)/Summit (U_s)	$U_g = -2 + 0.8U_s$	(mathematical derivation)		

better correlation using daily means than hourly means because the time-lag effect is reduced, and averaging over a longer period smoothes out short-term variations.

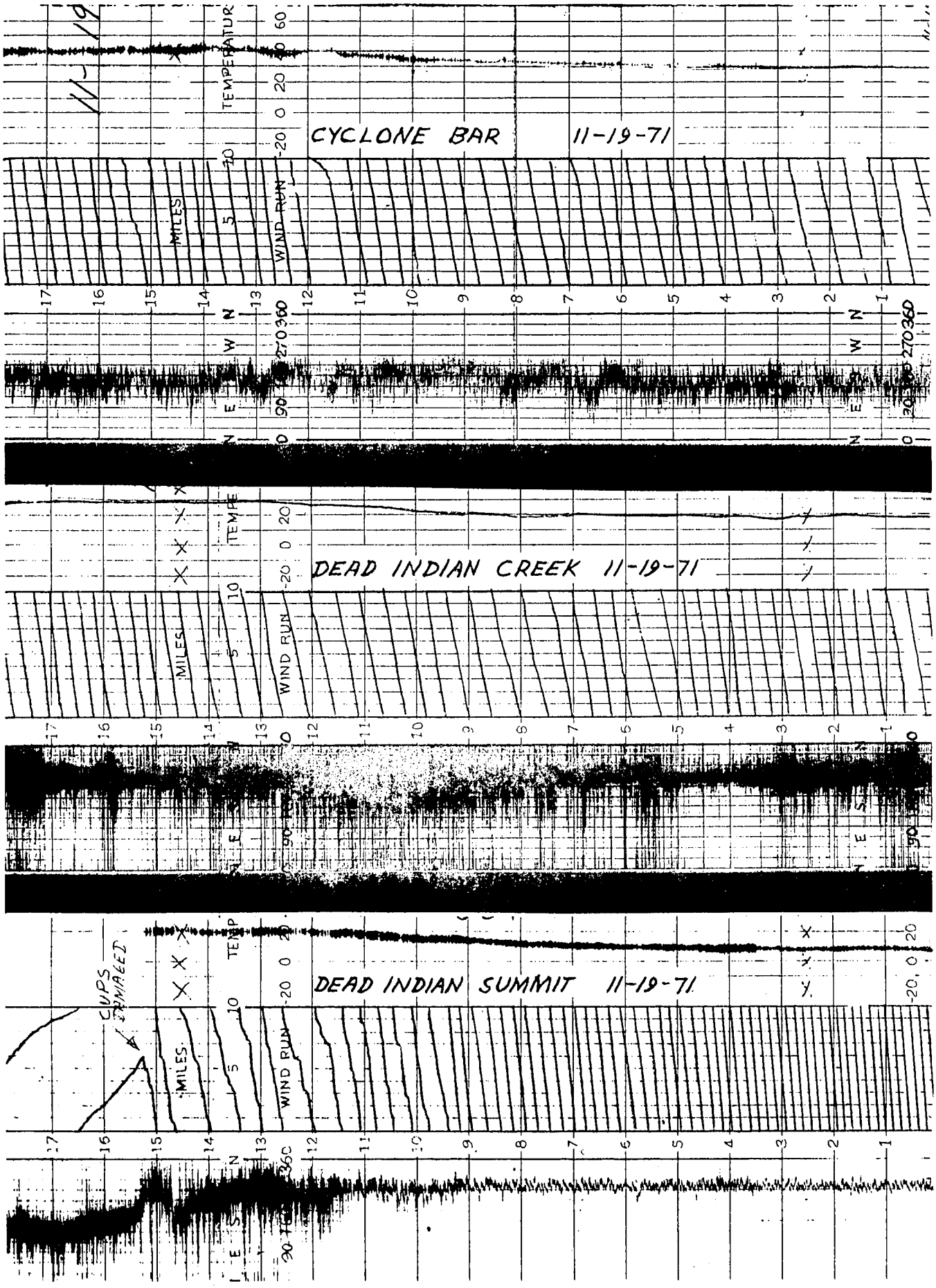


FIGURE 9. Concurrent wind records at the three weather stations during the wind storm of November 19, 1971.

Figure 10 demonstrates the apparent relationship between station elevation and windspeed. When mean hourly or daily windspeeds at the summit are less than 30 mph, the relationship is concave-up, which may be attributed to the effect of cold-air drainage (discussed later in this report). Summit windspeeds greater than 30 mph are associated with an opposite curvature, possibly reflecting the effects of turbulence and drag as the wind is deflected through the canyon.

Although the windspeed relationship between stations is complex, an approximation is that for mean daily speeds greater than 20 mph the Canyon and Gulch stations registered about 60 and 70% of the summit windspeed, respectively.

Wind direction.--Wind directions at both Dead Indian Gulch and at the summit are similar, with both indicating the prevailing westerly flow of upper-level winds (Figs. 11 and 12). Lower windspeeds are slightly more northerly, while the stronger flow tends to deviate 15 to 30° south of west. There is no conclusive indication of significant terrain effects on mean wind direction at either location, although records from both sites show pronounced rapid fluctuations in direction indicating turbulence generated by local terrain features. By comparison, wind direction in the canyon is dramatically influenced by the topography (Figs. 11 and 12). The lightest winds in the canyon appear to be associated with the flow of cold air down Falls Creek, oriented about 345° with respect to the anemometer. Winds from 10 to 19 mph reflect the more pronounced nocturnal cold air drainage down the Clarks Fork Canyon, which bears about 220° from the anemometer for a distance of 1 mile upstream, and about 200° averaged over a 2-mile reach upstream. The wind direction is comparatively uniform when caused exclusively by the flow of cold air down the canyon or the Falls Creek tributary (see Fig. 14 for an example). This stability contrasts with the larger fluctuations indicating greater turbulence when windspeeds exceed 30 mph (Fig. 9).

The mean directions of 170 to 180° (Fig.11) suggest deflection of the westerly winds by the south wall of the canyon and Bald Ridge, which rises about 3000 feet above the anemometer site. Figure 13 suggests a general pattern of surface wind deflection by terrain, based on results from this study.

During the winter, wind flow up the canyon (45°) is usually associated with the arrival of a cold air mass from the northeast. Windspeeds are light, and temperatures unusually low, during these events.

Cold air drainage.--After nightfall, cooling of the air is most rapid on the higher slopes and crests of the mountains. Because the density of air increases as it cools, the cold air has a tendency to flow downhill under the influence of gravity. This katabatic flow

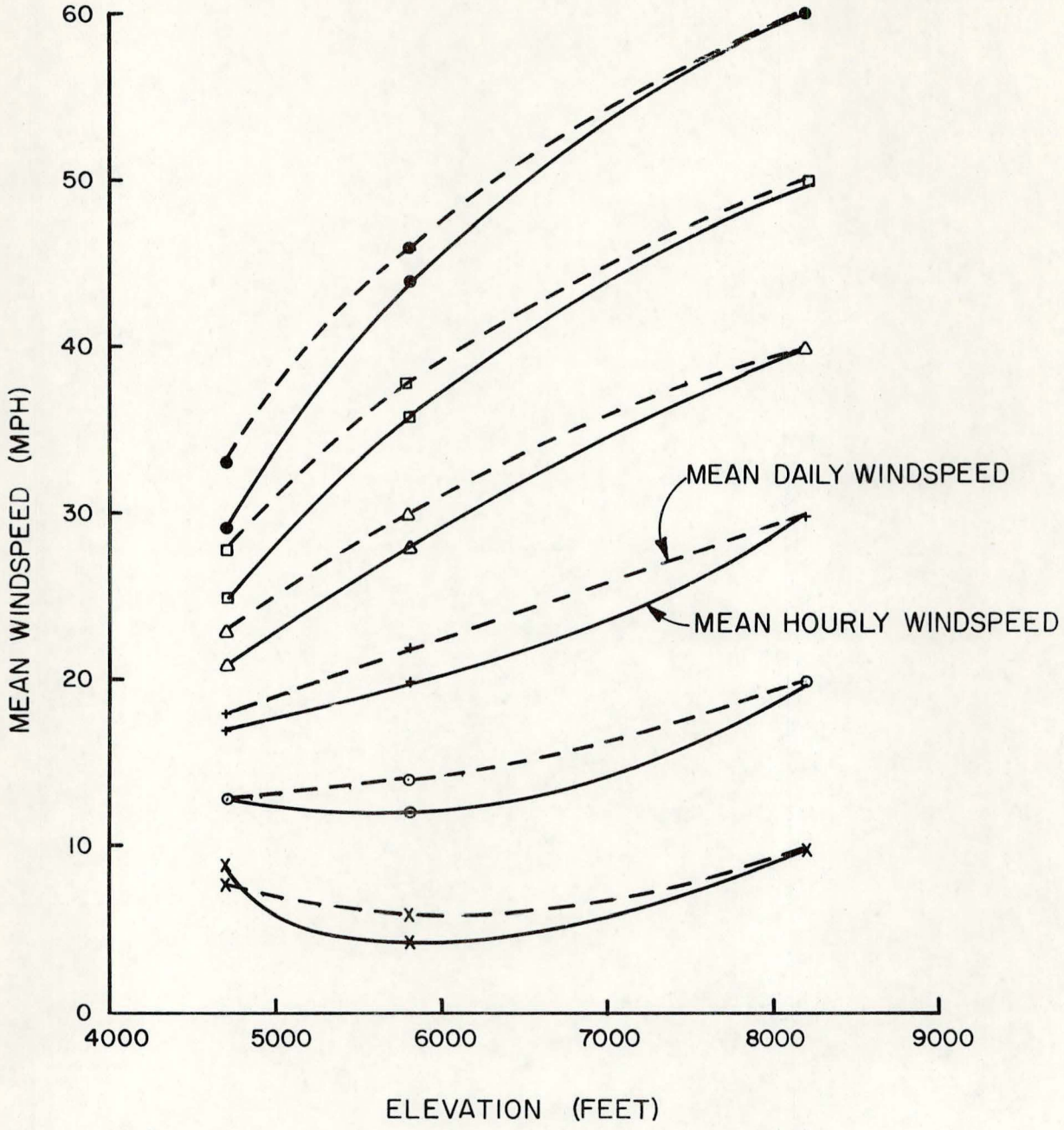


Figure - 10. Apparent relationship between windspeed and elevation, for various windspeeds at the summit (Based on regression equations comparing the three weather station sites).

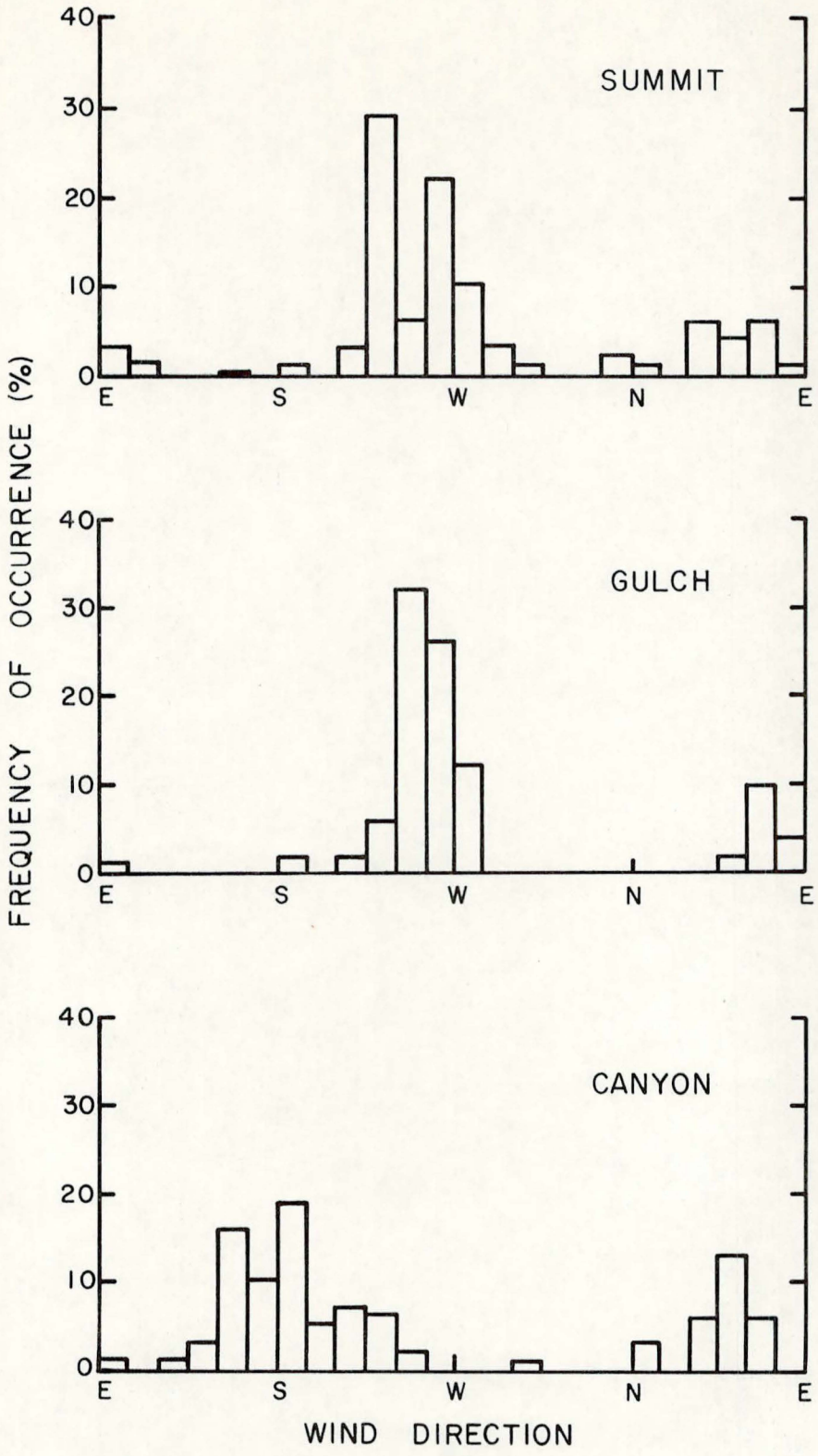


Figure 11. -- Frequency of mean hourly wind direction at the three weather station sites (November 16, 1971 to May 1, 1972).

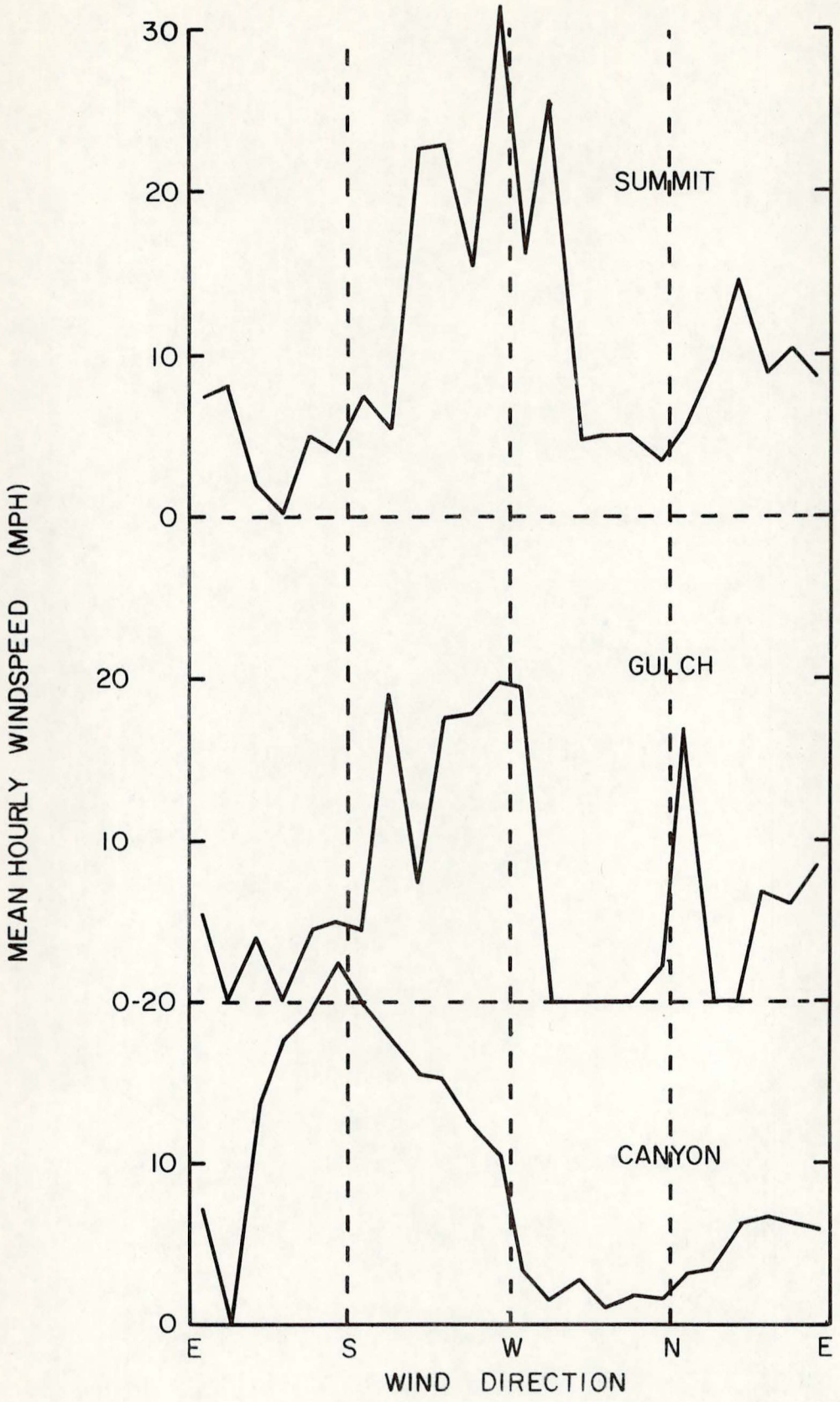


Figure 12. Relation between mean hourly windspeed and direction at the three weather station sites (Nov. 16, 1971 to May 1, 1972).

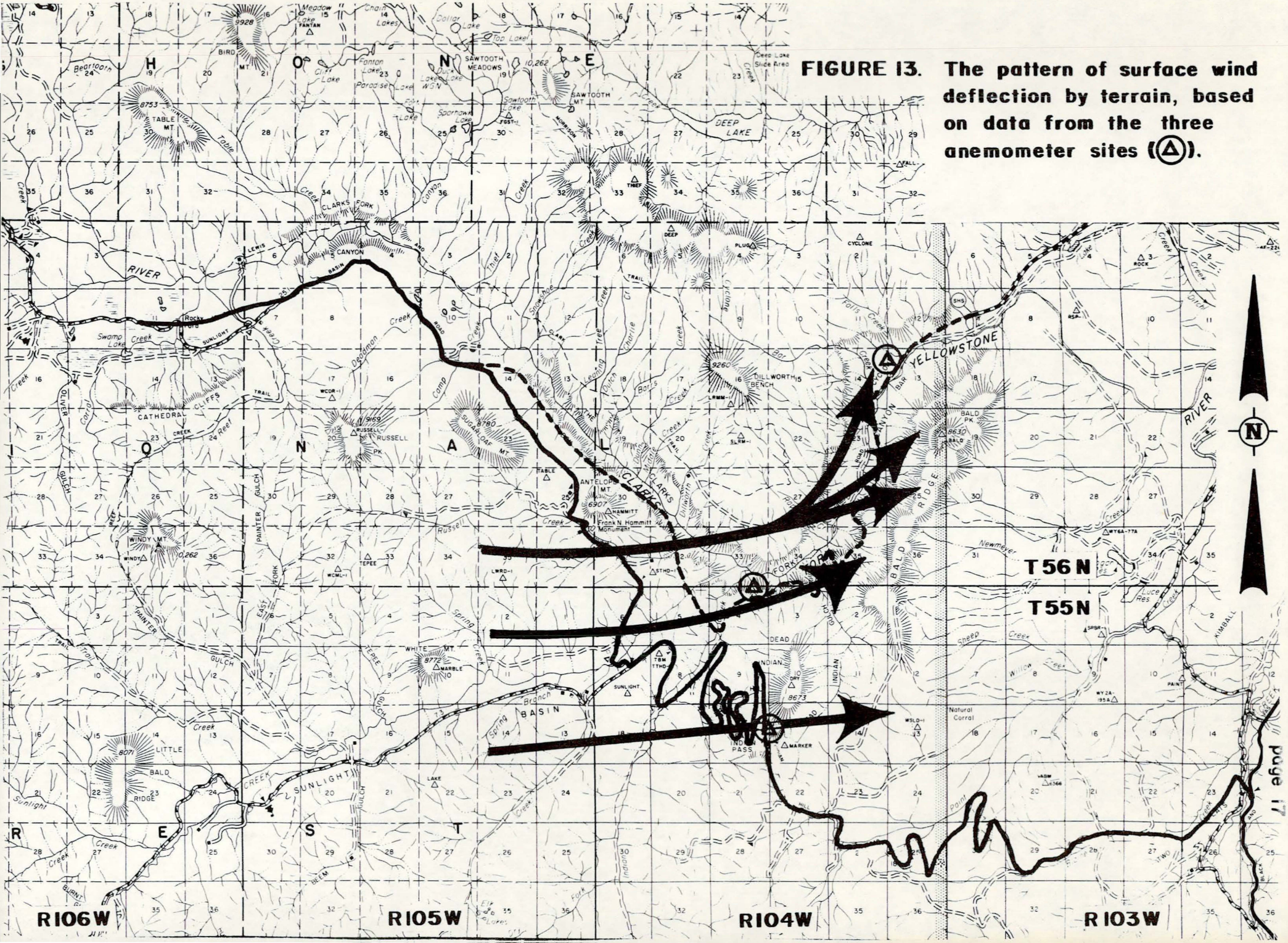


FIGURE 13. **The pattern of surface wind deflection by terrain, based on data from the three anemometer sites (△).**

("gravity wind") is collected and concentrated by the drainage system much the same as water, and the flow can reach speeds exceeding 20 mph as it pours down the lower canyons of mountainous terrain. This phenomenon is an impressive feature of the wind regime in the Clarks Fork Canyon. Averaging 15 to 20 mph, cold air drainage commences about 8 p.m. and continues until about 11 a.m. the following day. These winds are characterized by a steady direction usually coinciding with the orientation of the canyon immediately above the point of measurement (220^{o}, or $S40^{o}W$, for the Canyon weather station site; see Figs. 12 and 13). For cold air drainage to be well-developed in the canyon, windspeeds at the summit usually must average less than 20 mph. This phenomenon was observed on eight different dates (Table 5), or about 20% of the time when concurrent records from both the canyon and one of the two higher sites were available; peak hourly windspeeds were typically 20 to 25 mph. Examples of records showing cold air drainage are shown in Figures 14 and 15.

Table 5. Comparison of wind and temperature conditions during periods of cold air drainage in the Clark's Fork Canyon

Date	Hour	Cyclone Bar				Upper Station				
		$\overline{V}$ (mph)	$V_{max.}$ (mph)	Az (Deg.)	$\overline{T}$ (°F)	Station	$\overline{V}$ (mph)	$V_{max.}$ (mph)	Az (Deg.)	$\overline{T}$ (°F)
11/17-18/71	20-1200	16	20	-	- 5	Summit	8	11	285	+ 2
11/30	00-1000	14	17	220	+21	Gulch	5	10	255	+11
1/22 - 23/72	22-1100	17	22	200	+32	Summit	15	26	260	+15
2/1 - 2	21-1000	20	26	240	- 7	Gulch	9	15	240	-16
2/9 - 10	20-1100	20	26	230	+18	Summit	15	21	260	+ 8
3/21 - 22	20-1100	19	25	225	+47	Gulch	5	10	240	+37
3/27 - 28	21-0900	15	20	225	+19	Summit	9	10	225	+ 5
3/28 - 29	21-0800	14	15	215	+18	Gulch	6	7	240	+11

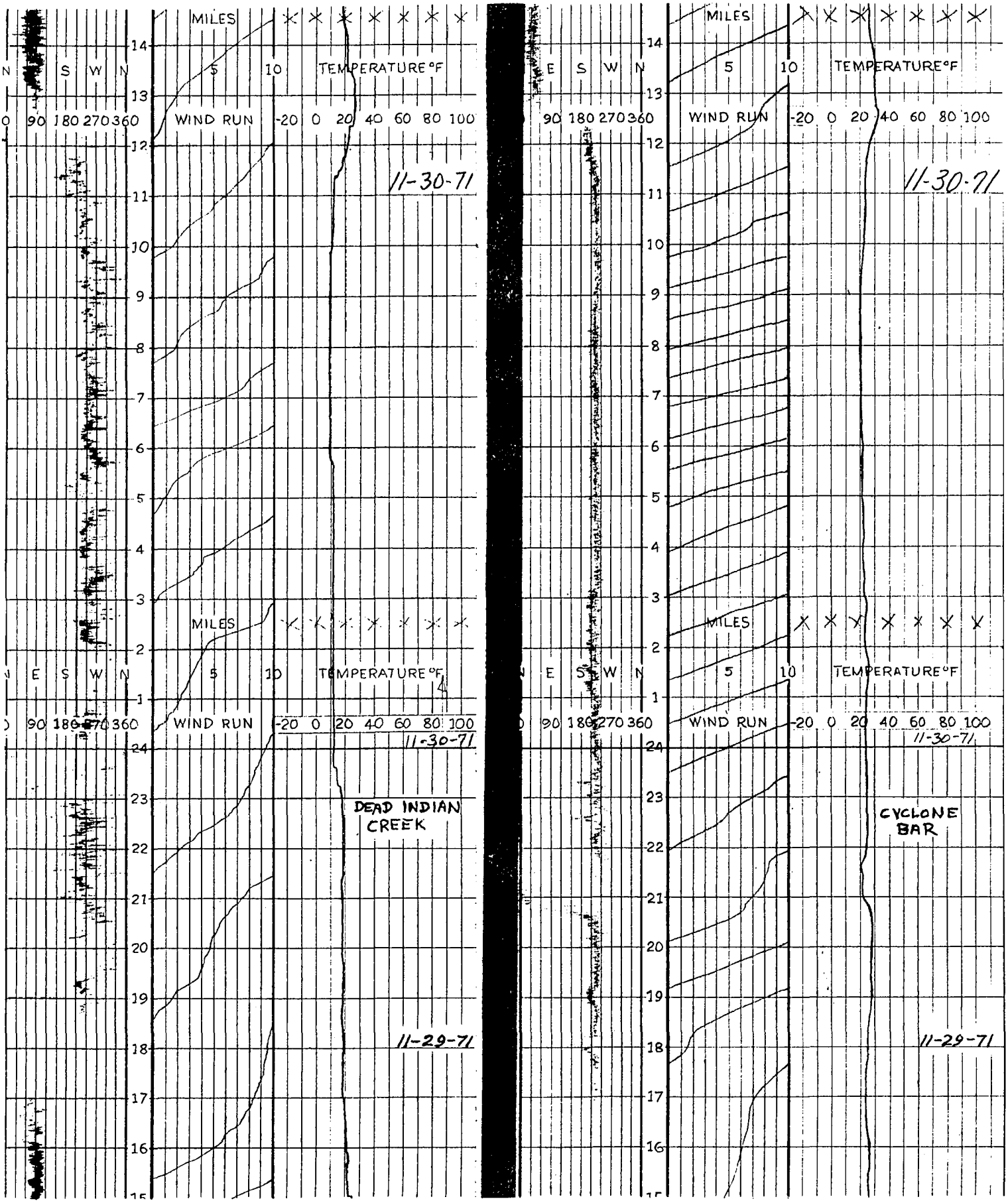


FIGURE 14. Concurrent wind records at Dead Indian Creek ("Gulch") and Cyclone Bar ("Canyon") showing cold-air drainage down the canyon on November 29-30, 1971.

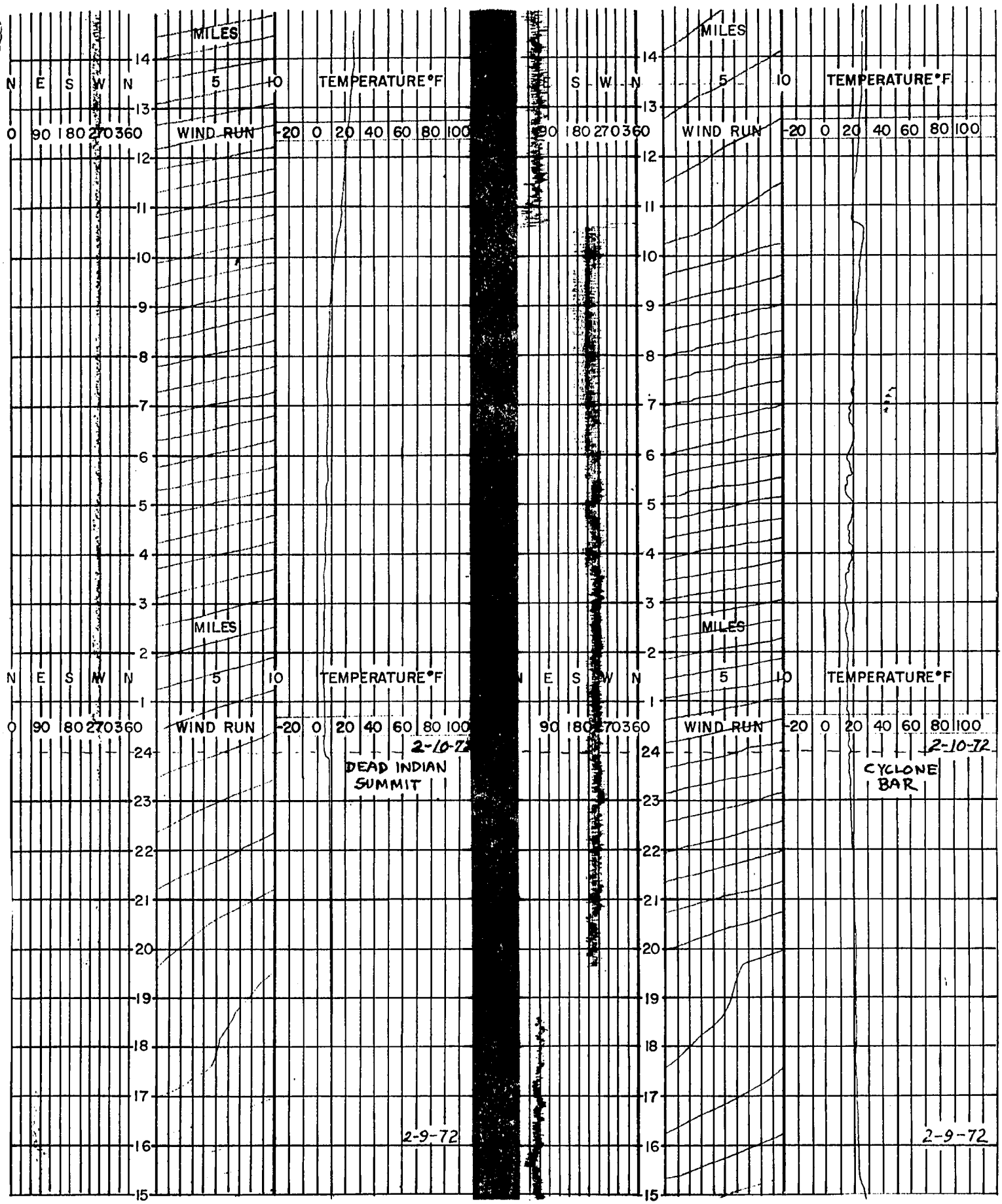


FIGURE 15. Concurrent wind records at Dead Indian Summit and Cyclone Bar ("Canyon") showing cold-air drainage down the canyon on February 9-10, 1972.

Temperature.--Because of the limited temperature data from the Summit and Gulch sites, discussed earlier in this report, the temperature frequency distribution is shown only for the Canyon location (Fig. 16). It is interesting to note that canyon temperatures were above 32°F about 50% of the time. Comparisons of mean hourly air temperatures at the three weather stations (Table 6) reflect the complex effects of elevation, cold air drainage, local net radiation, and differential advection. Parametric solution of the regression equations (Fig. 17) demonstrates that the relationships between stations are temperature dependent. Assuming a linear relationship between temperature and elevation, let

$$\Delta T/\Delta E = \frac{T_1 - T_2}{E_1 - E_2} \qquad (1)$$

where $\underline{T}$ and $\underline{E}$ are the mean hourly temperatures and elevations,

Table 6. Correlations between mean hourly temperatures (°F) at the three observation sites

Comparison	Equation	Correlation coefficient (r)	N	Standard Error (S_y)
Canyon(T_c)/Summit(T_s)	$T_c = 7 + 1.35T_s$	0.83	1057	0.03
Canyon(T_c)/Gulch(T_g)	$T_c = 5 + 1.13T_g$	0.96	1074	0.01
Gulch(T_g)/Summit(T_s)	$T_g = 2 + 1.19T_s$	(mathematical derivation)		

respectively, at stations 1 and 2. Substituting Eq. (1) in the linear regression equations of Table 6, and solving for an average value in terms of the Summit station (T_s) gives

$$\Delta T/\Delta E = -0.0014 - 0.0001\ T_s \qquad (2)$$

Equation (2) gives values approximating the relationships shown in Figure 17, indicating that the difference between two stations is in simple proportion to air temperature. When the Summit temperature is +10°F, temperature decreases at approximately 2.5°F/1000-ft increase in elevation. When the summit is at +40°F, temperature change is about -5.5°F/1000 ft.

If a mean winter temperature of +17°F is assumed for the summit, as suggested by the data from this study, then the average change in temperature would be about -3°F/1000 ft of elevation. This approximates the dry adiabatic lapse rate, and also agrees with the value

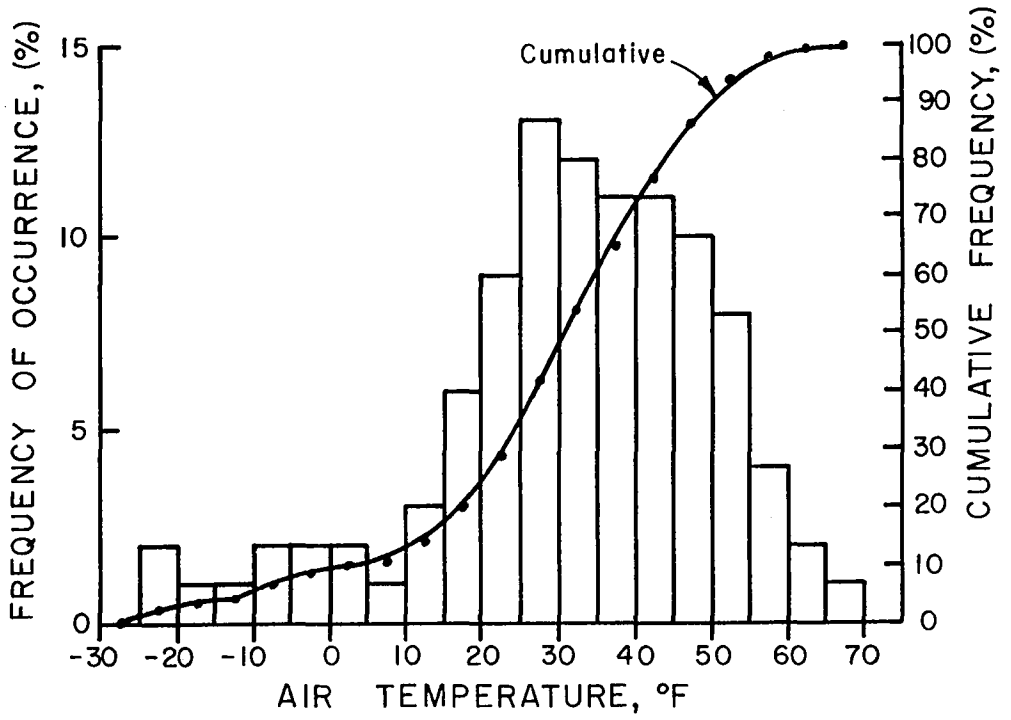


Figure 16.-- Distribution of air temperatures (2-meter height) at the Canyon site near Cyclone Bar (November 16, 1971 to May 1, 1972).

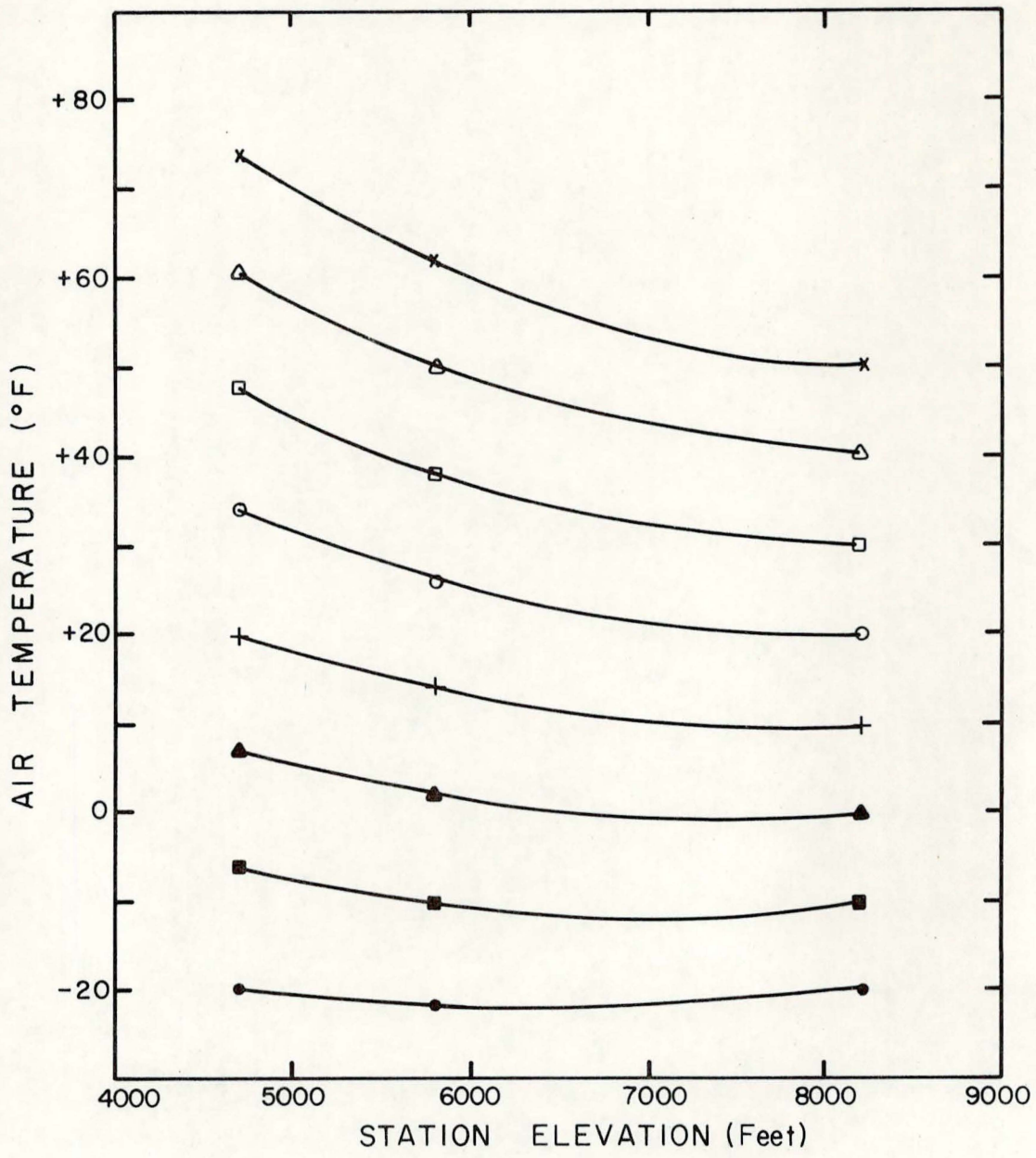


Figure 17. -- Apparent relationship between air temperature (at 2-meter height) and elevation, for various temperatures at the Summit (based on regression equations comparing the three weather station sites).

of -2.7°F derived from an analysis of published records from twelve selected National Weather Service stations (Fig. 18).

Some generalizations concerning the temperature regime, and their possible effects on road conditions, are useful for comparing the Summit and Canyon corridor locations. Winter daytime temperatures in the canyon probably average about 10 to 15°F warmer than those at the summit, due to the adiabatic lapse rate and the greater net radiation from reflection and reradiation of energy by the westerly-facing canyon walls. This implies that snow accumulation on a road following the "south" side of the canyon would melt rapidly compared with that on a road over Dead Indian Pass. Diurnal variations in temperature are greater on the summit than in the canyon; however, freeze-thaw cycling would be more frequent in the canyon, because the mean temperature is much closer to freezing in that location. Ice formation on a canyon road could be expected to occur at night following each day of melting. A summit road, by comparison, would be more likely to retain a snowpack for a few days after each storm, before being replaced by ice. Nocturnal cold air drainage could bring about freezing of melt water (or rain) very quickly, particularly on bridges near the bottom of the canyon.

The implications of temperature on snow control will be discussed in a later section of this report.

Precipitation.--Total precipitation at the two gages on Dead Indian Hill was about equal, averaging 9.48 inches for the period November 16, 1971 to May 1, 1972 (Table 7). Precipitation at the Crandall Creek gage (as reported by the National Weather Service) was 9.57 inches for the same period. The ratio between catches at the Dead Indian Hill gages and Crandall Creek varied from 0.79 to 1.38 over the five servicing intervals. This suggests the possibility of approximating the mean winter (Nov. 1 to Apr. 1) precipitation on Dead Indian Hill with the long-term mean of 5.7 inches at Crandall Creek. If this estimate is valid, the 1971-72 value of 8.95 inches has been exceeded only three times (1943, 1956, and 1957) in the past 34 years.

Table 7. Precipitation (inches) during the 1971-72 winter measured at the three study gages and the Crandall Creek station of the National Weather Service.

Period	Dry Fork (#1)	Summit (#2)	Camp Creek (#3)	Crandall Creek (NWS)
11/16/71-12/8	1.51	1.99	2.10	1.65
12/8-1/21	2.49	2.87	3.54	2.53
1/21-2/8	1.71	1.44	0.99	2.00
2/8-3/7	1.59	1.59	1.99	2.02
3/7-5/1/72	2.28	1.50	1.16	1.37
Total	9.58	9.39	10.83	9.57

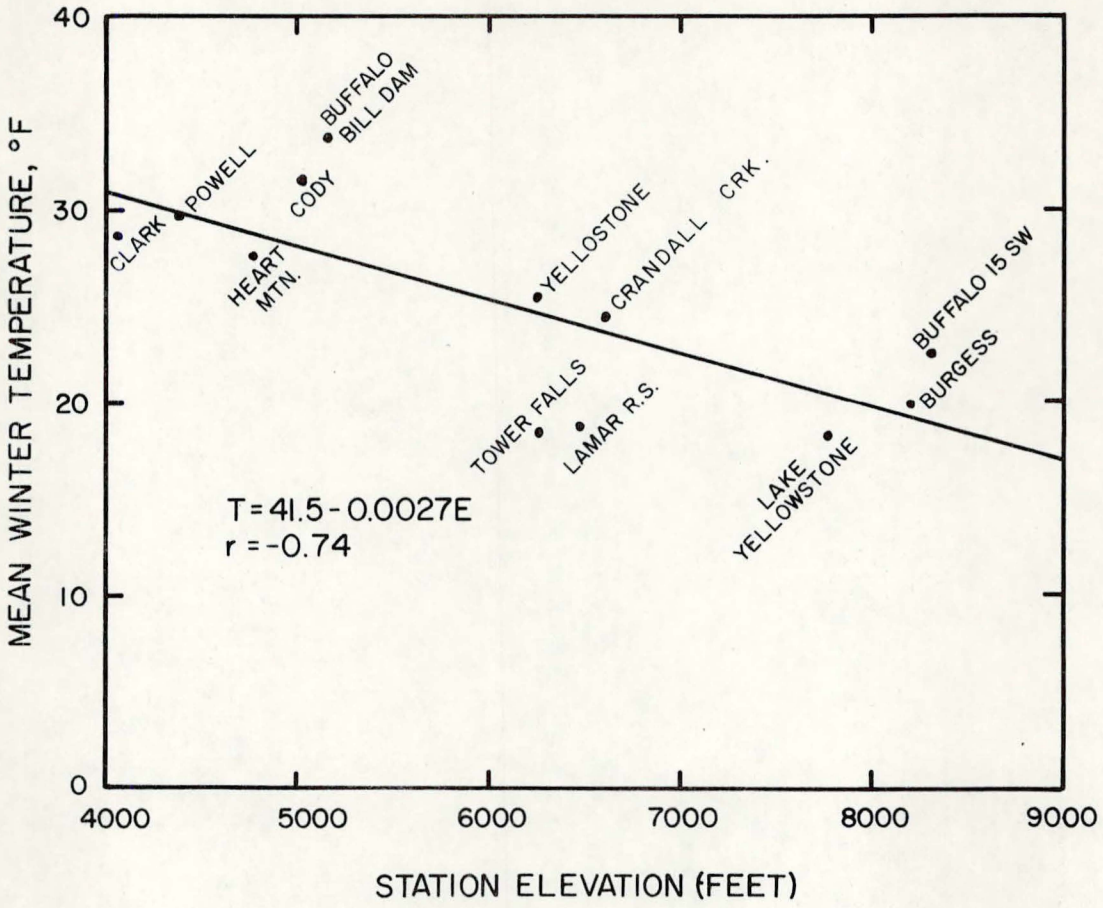


Figure 18 - Relationship between mean winter (Nov.1 to Apr.1) temperature and elevation for selected stations (From data published by National Weather Service).

To estimate precipitation at elevations below the Dead Indian Hill gages, a linear decrease in precipitation with decreasing elevation was assumed. Using the long-term record published by the National Weather Service for Clark, winter (November 1 to April 1) precipitation was estimated to be 1.7 inches at the 4200-ft elevation. Thus, mean winter precipitation P_e at elevation E, on the east side of Dead Indian Hill, is described by

$$P_e = -2.7 + 0.00105E \qquad (3)$$

indicating about a 1.0 inch increase in precipitation for each 1000-ft increase in elevation. Equation (3), which is used in the next section to estimate the amount of snow fencing required on the summit route, applies only to the area between Wyoming 120 and Dead Indian Creek. Precipitation along the Clarks Fork road west of Sunlight Creek would appear to be better approximated by

$$P_w = -1.0 + 0.00105E \qquad (4)$$

although at least one more winter's data would be needed to verify this estimate.

SNOW CONTROL

Introduction.--An important consideration in comparing alternative corridor locations is that of the cost required for snow control, assuming that the Clarks Fork road is to be kept open during the winter.

Although it is impossible to accurately predict the amount and placement of snow fencing before the final highway location and design are known, a useful approximation can be made by examining snow accumulation patterns along the existing Sunlight Basin road. As part of this study, Wyoming Highway Department engineers assisted the author in identifying snow accumulation areas and measuring wind directions at each site, as indicated by drift orientation. Complementing this data, a complete set of aerial photos (approximate scale 1 inch/1000 ft) was taken along the Sunlight road on January 31, 1972.

Methods.--The general methods used to estimate the amount and placement of snow fences required on the Clarks Fork road have been fully described in an earlier report to the Wyoming Highway Department, in which the author proposed the snow fence system presently being constructed on Interstate-80 in southeastern Wyoming (Tabler, 1971). Briefly, the method is based on the fact that snow particles evaporate as they are blown along by the wind; the maximum distance an average-sized particle travels before completely evaporating is determined by its size, air temperature and relative humidity, and

solar radiation. This maximum distance of transport (R_m) can be calculated from a mathematical model formulated by Schmidt (1972), if values for the above variables are known. Although this data is not available for the area in question, other studies by the Rocky Mountain Forest and Range Experiment Station have shown the average distance for R_m to be about 3500 ft at 7500 to 8000-ft elevations in southeastern Wyoming (Tabler and Schmidt, 1972). A reasonable estimate of R_m for Dead Indian Pass (elev. 8000 ft) would be about 4000 ft.

The total amount of blowing snow over a winter can be estimated at a site by

$$Q = \tfrac{1}{2}\,\theta P R_c \qquad (5)$$

where Q is the water-equivalent of the snow in ft^3 per ft of distance normal to the wind, θ is the "snow transfer coefficient" (ratio of the snow that is relocated to that which falls as precipitation), P is the precipitation during the period November 1 to April 1 (ft), and R_c is the upwind fetch (ft), or open area without natural barriers up to, but not exceeding, R_m. For locations without natural barriers over the maximum distance of transport, average values for the total amount of blowing snow can be calculated from

$$\bar{Q} = \tfrac{1}{2}\bar{\theta}\,\bar{P}\,\bar{R}_m \qquad (6)$$

All of the independent variables in the above equation are functions of elevation. For the Clarks Fork analysis, use was made of the precipitation-elevation relationships developed earlier in this report. Rough approximations for θ would be 1.0 at 8000 ft and 0.5 at 4000 ft. Thus,

$$\bar{\theta} = 1.25 \times 10^{-4} E, \quad E \leq 8000 \text{ ft} \qquad (7)$$

All of the variables affecting sublimation rate, and thus R_m, vary with elevation as well; it is theorized that temperature and relative humidity are the factors with elevation changes having the greatest effect on sublimation rate. Unfortunately, quantitative data is lacking on the relationship between relative humidity and elevation during drifting, although superficially it might be assumed that relative humidity decreases with elevation in proportion to the temperature effect on relative humidity.

To estimate the quantities of blowing snow on the Clarks Fork road, the only elevation adjustment for R_m was that for temperature; the complexity of the relative humidity correction can hardly be justified for the present estimate of snow fence requirements. Schmidt (1972) found that for each 10°C increase in temperature, sublimation rate approximately doubles (thus halving the maximum transport distance). The temperature-elevation relationship of Figure 18 was used to account for this effect of elevation on transport distance.

Combining all the above elevation-dependent relationships, and substituting in Eq. (6), we arrive at the final expressions for estimating the amount of blowing snow available at an open site where $R_c = R_m$:

$$\overline{Q}_e = -2.25 \times 10^{-2} E + 4.58 \times 10^{-6} E^2 + 1.7 \times 10^{-9} E^3, \quad E \leq 8000 \text{ ft} \quad (8)$$

where $\overline{Q}_e$ estimates the mean amount of blowing snow for sites at elevation E, on the east end of the project between Dead Indian Creek and Wyoming 120.

Blowing snow amounts at sites west of Sunlight Creek ($\overline{Q}_w$) were similarly estimated from

$$\overline{Q}_w = -8.3 \times 10^{-3} E + 7.24 \times 10^{-6} E^2 + 1.7 \times 10^{-9} E^3, \quad E \leq 8000 \text{ ft} \quad (9)$$

Estimates of snow fencing and comparisons between routes.--The values given by Eqs. (8) and (9) are plotted on the profiles of the road locations in Figure 19, providing a visual comparison of alternate routes with respect to blowing snow. To interpret these values in terms of snow fencing, the 8- and 12-ft-tall fences used by the Wyoming Highway Department can store about 400 and 800 ft^3 of water-equivalent per ft of length, on level terrain.

For each drifting area identified from the study of the existing road, wind direction and contributing distance were determined from the aerial photos. Equation (5) was then used to calculate the amount of snow fencing required at each of these sites (Table 8). As a first approximation, it may be assumed that little or no fencing would be required on the Canyon route east of Dead Indian Creek. By comparison, approximately 30,000 ft of 8-ft-tall fence and 5,000 ft of 12-ft fence would be required on the Summit route. Using 1971 contract prices for the I-80 snow fences, this amount of fencing would cost about $230,000; however, these prices could not be expected to apply to the Clarks Fork Road and are given only as an example.

West of Sunlight Creek, it is assumed that the two routes would require approximately equal amounts of snow fence protection. However, it is much more difficult to estimate snow fence requirements on this portion of the project because blowing and drifting snow conditions will be sensitive to the exact location, alignment, and cross-section of the road in relation to the forest cover which predominates north of Russell Creek.

A very rough estimate of the snow fencing required to protect the existing Sunlight Basin road between Dead Indian Creek and Swamp Lake, is 18,000 ft of 8-ft fence and 7,000 ft of 12-ft fence, or about 75% of that required on the Summit route east of Dead Indian Creek. This estimate could be an order of magnitude too low should the highway not be designed with the utmost consideration for blowing snow

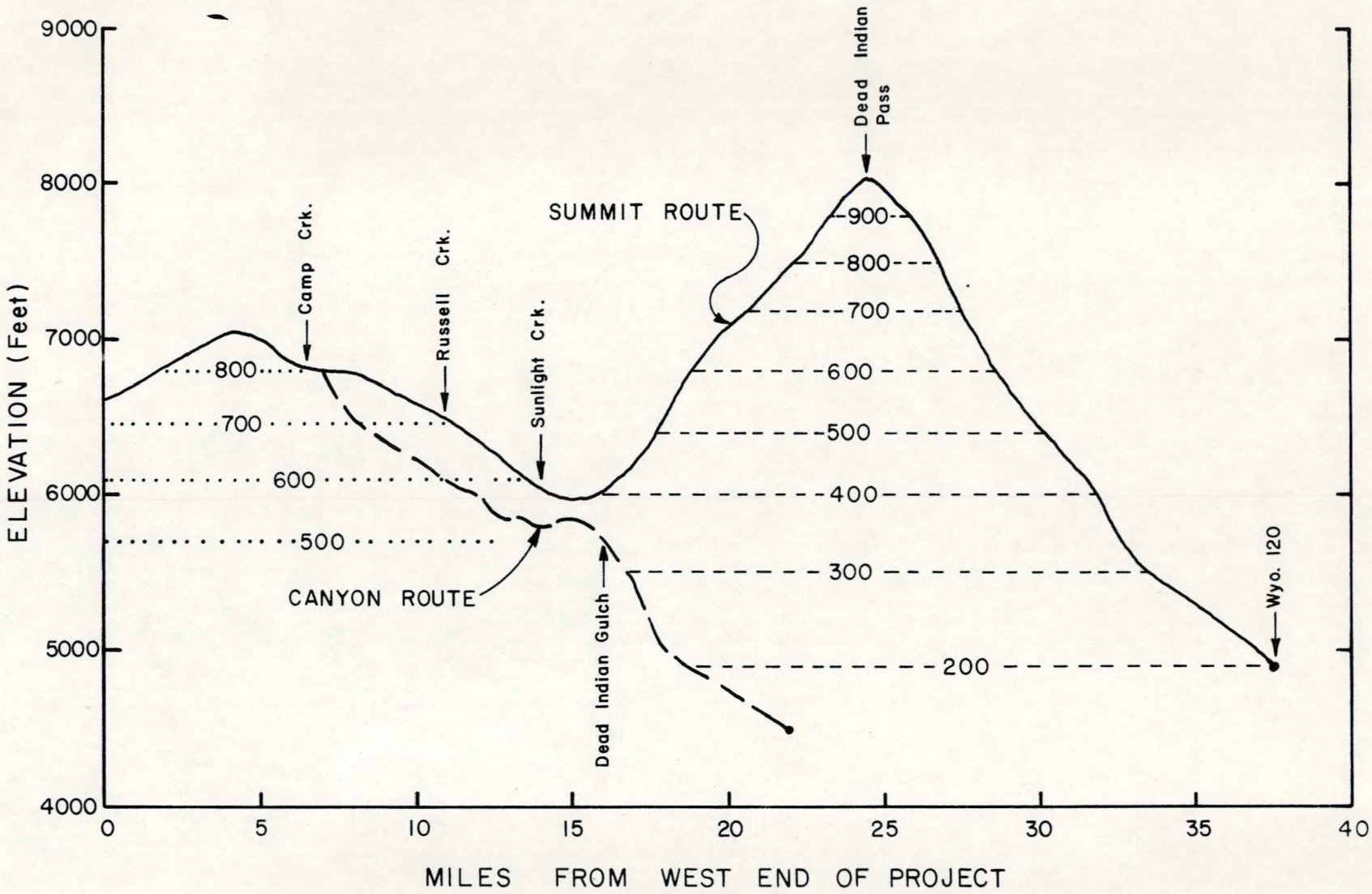


Figure 19. -- Approximate profiles of the Canyon and Summit routes, showing estimated quantities of blowing snow in areas with maximum possible fetch. Numbers are total ft^3 of Water-equivalent per lineal ft. of width (perpendicular to wind) over an average winter.

Table 8. Snow accumulation sites, and estimated protection requirements, along the existing Sunlight Basin road between Wyoming 120 and Dead Indian Creek (from observations during the 1971-72 winter). Milepost locations are miles from the junction with Wyoming 120 (westbound).

Site No.	West-bound Milepost	Length (ft)	Elevation (ft)	Wind Azimuth*		Fencing Required (ft) (Ht. x Length)
				Field msmt.	Photo msmt.	
1	0.20 to 0.45	1400	5000	300	270	8 x 1200
2	2.40 to 2.65	1300	5200	245	250-280	8 x 1200
3	3.86 to 4.10	1200	5500	277	280	8 x 1100
4	4.92 to 5.70	4000	5900	277	280	8 x 3800
5	5.98 to 6.37	2100	6200	277	270	8 x 4700
6	6.40 to 7.15	3900	6400	277	270	
7	7.15 to 7.62	2400	6600	302	270	
8	8.15 to 8.62	2400	6800	302	270	8 x 2400
9	8.65 to 9.05	2200	7000	302	270	8 x 1900
10	9.32 to 9.49	900	7100	312	270	8 x 800
11	9.58 to 9.65	400	7200	277	270	8 x 400
12	9.71 to 9.89	1200	7200	277	270	12 x 900
13	10.10 to 11.01	4600	7400	253	260	8 x 1000

Continued

Table 8. Continued

Site No.	West-bound Milepost	Length (ft)	Elevation (ft)	Wind Azimuth*		Fencing Required (ft) (Ht. x Length)
				Field msmt.	Photo msmt.	
14	11.01 to 11.24	1000	7600	253	260	8 x 1200
15	11.24 to 11.47	1200	7600	247	270	8 x 400
16	11.47 to 12.28	4500	7700	279	260	8 x 2100 12 x 3200
17	13.02 to 13.15	600	8000	315	260-280	8 x 600
18	13.98 to 14.15	900	7700	300	280	8 x 1000
19	14.95 to 15.12	800	7500	349	280	8 x 1000
20	15.82 to 16.01	900	7300	300	280	8 x 600
21	16.47 to 16.70	1200	7200	300	280	8 x 900
22	17.90 to 18.09	1000	6800	300	280	8 x 900
Totals		40,100				8 x 27,200 12 x 4,100

* Wind azimuth is measured in degrees clockwise from True North. Field measurement was made late in March, 1972. Aerial photos were taken January 31, 1972.

conditions. Every effort should be made to keep the road surface on sufficient fill (4 ft or more above the existing grade, where possible), maintain backslopes and fills at sufficiently low angles (4:1 or 6:1) so as not to induce drift formation, maintain the location as close as possible to the south side of forest openings, retain as much forest protection as possible along the right-of-way, and avoid long corridors parallel with the wind through forested areas.

Examples of snow conditions on the Sunlight Basin road in March, 1972, are shown in Figures 20-24. The location on Dead Indian Hill requiring the most extensive protection is the open park near the Dry Fork of Paint Creek (Fig. 21 and 22). Because of the high precipitation and long fetch (contributing distance), this area would require 12- and 8-ft-tall fences in tandem for complete protection during an average winter.

Conclusions.--Winter snow conditions over Dead Indian Pass are not as formidable as they might have appeared in the past, when viewed in light of the present technology of snow control and snow removal. Proper road design and location can, by themselves, substantially reduce winter maintenance problems. Although snow fences can greatly improve visibility during periods of blowing snow, poor visibility could still be expected to necessitate closure of a summit road for periods of hours or even days during the heavier storms. This study indicates, however, that snow conditions on Dead Indian Hill are not by themselves sufficient to justify an alternative route up the canyon. Winter travel over Dead Indian Pass promises to be no more severe than on many other mountain passes that are kept open year-long.

SUMMARY

A. General
   1. This report gives results of a preliminary study of winter weather conditions in the Clarks Fork-Dead Indian Hill area.

   2. Data on surface winds and air temperature were collected during the 1971-72 winter from stations at Cyclone Bar, Dead Indian Creek (near its confluence with the Clarks Fork River), and at Dead Indian Pass. Precipitation was measured at two gages on Dead Indian Hill and a third near Camp Creek.

   3. A preliminary study was also made of snow conditions on the existing Sunlight Basin road to estimate snow fence protection required on the Summit route.

B. Wind Conditions
   1. Maximum windspeeds recorded at the three sites were about the same, although the Summit had the strongest sustained winds.

Figure 20. The snow accumulation at Site 6 (elevation 6200 ft) is typical of that on the switchbacks leading up the Blaine Creek-Paint Creek divide. It is estimated that an 8 ft tall snow fence would keep this cut free of snow during an average winter. March 8, 1972

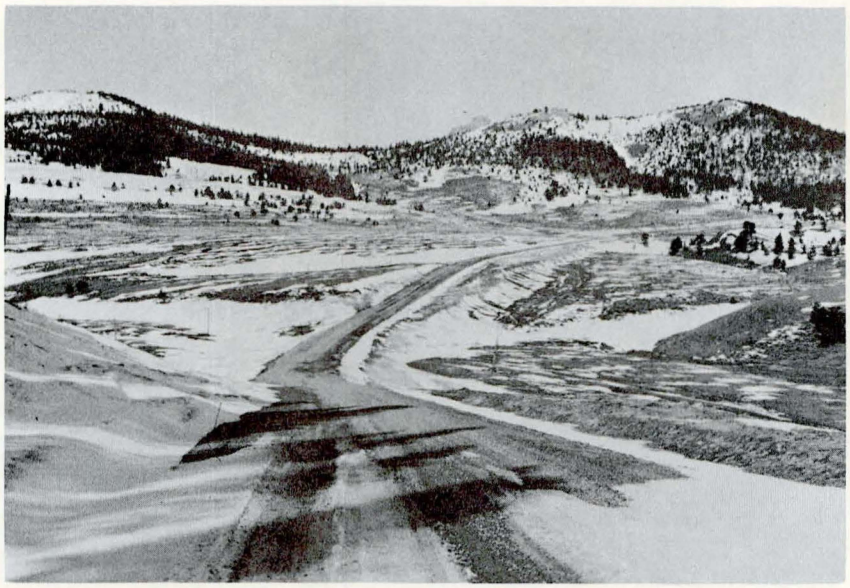
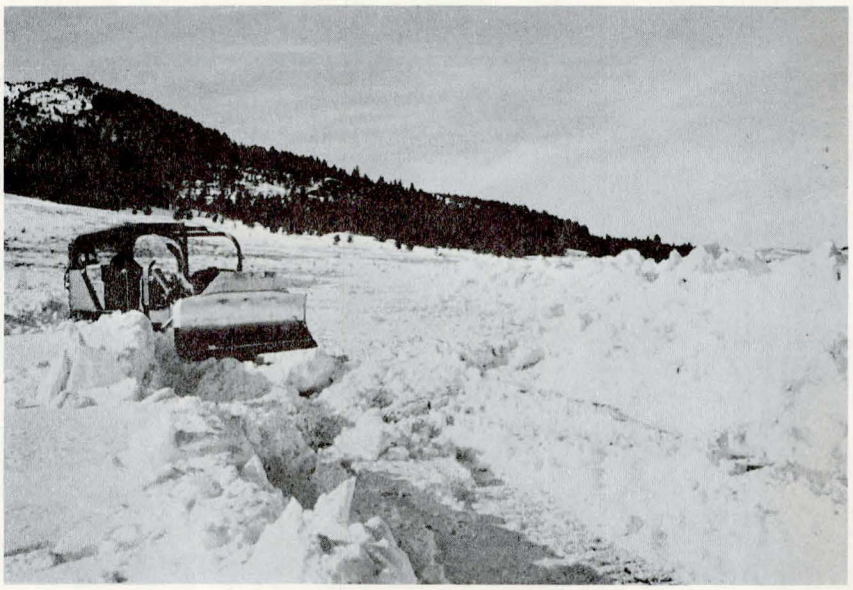


Figure 21. View west across Dry Fork of Paint Creek (Site 16, elevation 7500-7800 ft). Because of the high precipitation and long fetch, this area would require 12 to 8 ft tall fences in tandem for complete protection during an average winter. March 21, 1972. (Wyoming Highway Department Photo)

(A)



(B)

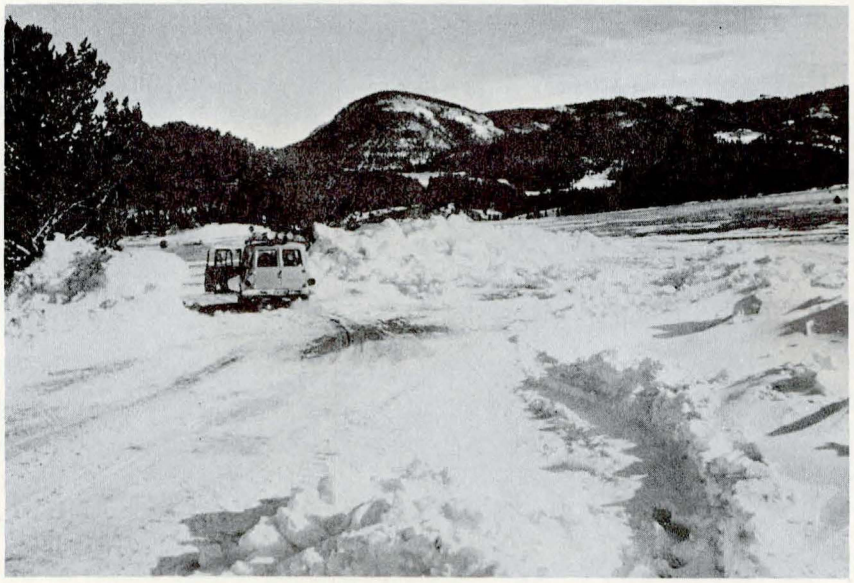


Figure 22. (A) Snow removal to open the Sunlight Road periodically during the winter presently adds to the maintenance problem, because piles of snow such as these induce deep drifts in areas that would otherwise blow free of snow. (B) Vehicles are forced to detour cross-country to avoid plowed areas that fill with snow after each drifting event. Dry Fork of Paint Creek, March 8, 1972.

Figure 23. Snow accumulation in a sheltered location near Site 25, one mile west of Russell Creek (elevation 6900 ft) March 8, 1972.

Figure 24. Snow conditions near Camp Creek (elevation 6800 ft) on March 8, 1972.

2. Strong winds are more gusty in the canyon than at the Gulch or Summit sites. This implies a potential hazard to traffic on the canyon route, particularly on bridges and near tunnel portals.

3. The prevailing wind direction at the Summit and Gulch sites is about 30° south of west, while that in the canyon is nearly due south. This indicates that air flow is deflected down the canyon, giving rise to the turbulence observed at Cyclone Bar. Convergence of airflow is responsible for the strong winds in the canyon.

4. Although the windspeed relationship between stations is complex, an approximation is that for mean daily speeds greater than 20 mph, the Canyon and Gulch stations registered about 60 and 70% of the summit windspeed, respectively.

5. Cold air drainage is a frequent and impressive feature of the wind regime in the Clarks Fork Canyon. Averaging 15 to 20 mph, these winds begin about 8 p.m. and continue until about 11 a.m. the following day. Summit windspeeds generally must average less than 20 mph for the phenomenon to be well developed.

C. Temperature

1. Temperature records at the Summit and Gulch sites were insufficient to estimate mean temperatures for the winter. In the canyon, temperatures were above 32°F about 50% of the time.

2. The relationship between concurrent temperatures at any two stations appeared to be related to both elevation and temperature; for example, the change in temperature with increasing elevation was found to be about -2.5°F/1000 ft when the Summit temperature was +10°F, and about -5.5°F/1000 ft when the Summit was +40°F. Assuming a mean winter temperature of +17°F for the Summit, the average differential for the winter would be about -3°F/1000 ft.

3. Winter daytime temperatures in the canyon average about 15°F warmer than those at the summit, due to the adiabatic lapse rate and the greater net radiation from reflection and re-radiation of energy by the westerly-facing canyon walls. Snow accumulation on a road traversing the "south" wall of the canyon would melt rapidly compared with that on a summit road.

4. Diurnal fluctuations in temperature are greater on the summit than in the canyon; however, freeze-thaw cycling would be more frequent in the canyon because the mean temperature is much closer to freezing in that location.

5. The nocturnal cold air drainage could bring about freezing of melt water (or rain) very quickly, particularly on bridges near the bottom of the canyon.

D. Precipitation

1. For the period November 16, 1971, to May 1, 1972, precipitation near Dead Indian Pass was 9.48 inches, while that recorded by the Crandall Creek gage near the west end of the project was 9.57 inches. This suggests the possibility of approximating the mean winter precipitation on Dead Indian Hill with the long-term mean of 5.7 inches at Crandall Creek. Precipitation gages on Dead Indian Hill should be operated for at least one more year to further test this possibility.

2. Analysis suggests an increase of about 1.0 inch per 1000 ft increase in elevation, for winter precipitation.

E. Snow control

1. Snow conditions on the existing Sunlight Basin road were studied to locate drift areas, determine mean wind direction responsible for drift formation, and to estimate the amount of snow fencing that would be required on the summit route. The canyon route would require little or no snow fence between Wyoming 120 and Dead Indian Creek, whereas about 30,000 ft of 8-ft- and 5,000-ft of 12-ft-tall fence would be required on the summit route between these same points.

2. It is assumed that equal amounts of snow fence would be required on the two routes west of Sunlight Creek, requiring in both cases about 75% as much snow fence as the summit route east of Dead Indian Creek.

3. Roads in either corridor should be designed with the utmost consideration for blowing snow conditions. Every effort should be made to keep the road surface on sufficient fill, maintain low angles for backslopes and fills, choose locations as close as possible to the south and west sides of forest openings, retain as much forest protection as possible along the right-of-way, and avoid long corridors parallel with the wind through forested areas.

4. Snow conditions on the summit route are not by themselves sufficient to justify an alternative route up the canyon. Winter travel over Dead Indian Pass promises to be no more severe than on many other mountain passes that are kept open year-long.

RECOMMENDATIONS FOR FURTHER STUDY

A. If the canyon corridor remains a viable alternative, a study should be made of the winds on the canyon's "south" wall between Cyclone Bar and Dead Indian Gulch. The primary objective should be to quantify gustiness along the canyon route and assess the hazard which might exist to traffic, particularly in the vicinity of bridges and tunnel portals.

B. Precipitation measurements should continue for one more year utilizing the present gage system to test the hypothesis that the long-term mean winter precipitation at Crandall Creek can be used as an estimate of precipitation on Dead Indian Pass.

C. An additional precipitation gage should be installed near Russell Creek to help improve estimates of snow fence requirements between Sunlight Creek and Camp Creek.

D. The identification and description of snow drift areas along the existing Sunlight Basin road should be repeated for the 1972-73 winter.

E. At least one more set of aerial photos should be taken in February, 1973, to help in determining wind directions associated with drifting.

F. The amount of snow water-equivalent stored in the large natural accumulation area near Camp Creek ("Ellsbury Flats") should be accurately determined at the time of next year's peak snowpack. This value should then be used to calculate the apparent transport distance using the method given in this report.

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Tabler, Ronald D., and R.A. Schmidt. 1972. Weather conditions that determine snow transport distance at a site in Wyoming. Paper accepted for presentation at the International Hydrologic Decade Symposium on the Role of Snow and Ice in Hydrology, to be held September 6-14, 1972 at Banff, Alberta, Canada. (13 p M/S).

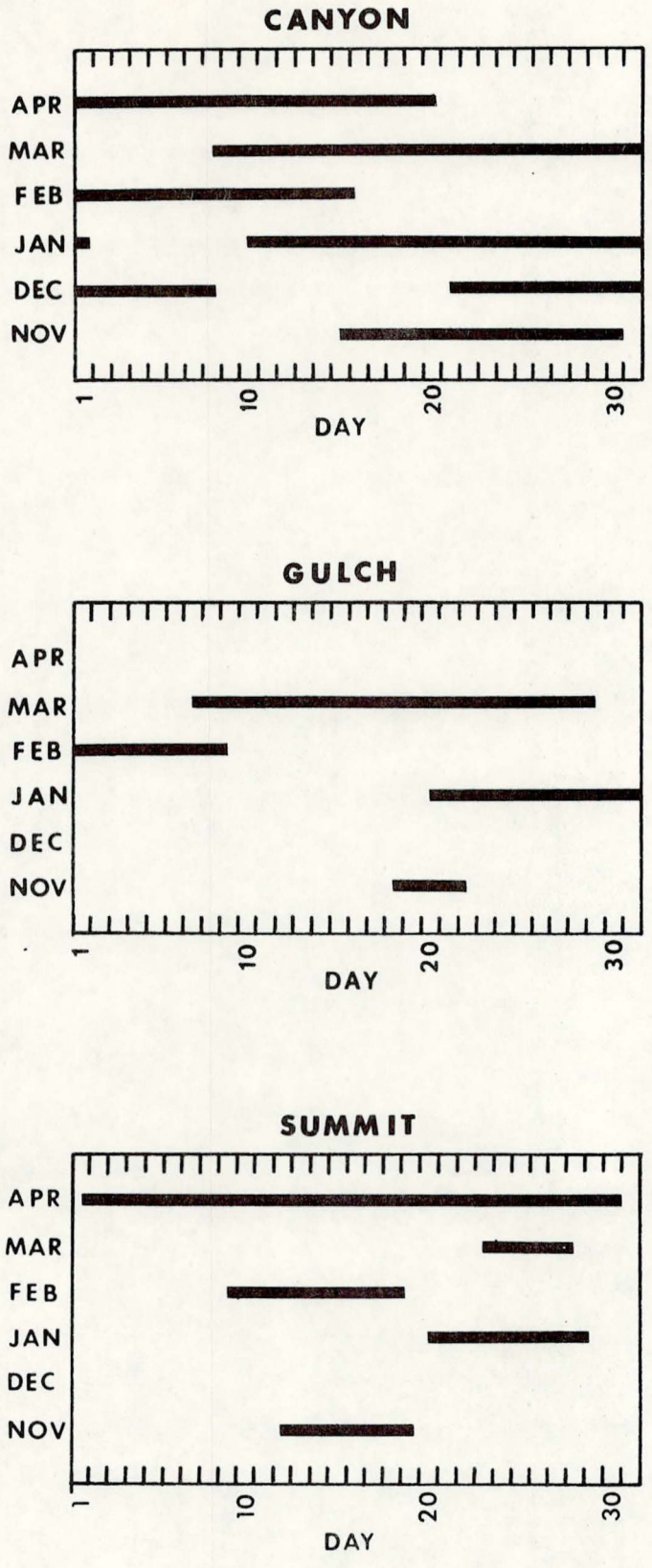
APPENDIX

A. Dates of record at the three weather stations

B. Tabulation of data by windspeed classes

C. Tabulation of data by wind azimuth classes

D. Tabulation of data by air temperature classes



A. Dates of record at the three weather stations, during the 1971-72 winter.

B. Tabulation by windspeed classes, showing number of hours (N), frequency (%), cumulative frequency ($\int$%), mean azimuth (in degrees clockwise from True North), and mean air temperature, for each class.

Wind Speed [mph]	CANYON					GULCH					SUMMIT				
	N	%	$\int$%	Azimuth	Temp.°F	N	%	$\int$%	Azimuth	Temp.°F	N	%	$\int$%	Azimuth	Temp.°F
0 4	441.	0.16	0.16	342.6	21.1	84.	0.08	0.08	283.4	1.7	141.	0.10	0.10	310.8	14.4
5 9	578.	0.21	0.37	348.7	21.8	222.	0.20	0.28	310.6	16.5	250.	0.17	0.27	278.5	17.8
10 14	449.	0.16	0.54	228.1	32.7	180.	0.16	0.44	286.4	26.5	203.	0.14	0.40	280.7	19.7
15 19	464.	0.17	0.70	184.0	38.0	191.	0.17	0.62	257.0	30.3	180.	0.12	0.53	298.5	22.5
20 24	406.	0.15	0.85	178.4	37.8	204.	0.19	0.80	252.0	28.5	199.	0.14	0.66	262.6	22.2
25 29	206.	0.08	0.93	177.8	35.7	112.	0.10	0.90	250.7	27.8	134.	0.09	0.75	244.6	23.9
30 34	118.	0.04	0.97	173.6	37.8	75.	0.07	0.97	254.8	24.7	141.	0.10	0.85	239.8	21.6
35 39	49.	0.02	0.99	179.0	35.4	12.	0.01	0.98	248.0	18.0	101.	0.07	0.92	247.2	20.7
40 44	23.	0.01	1.00	166.7	34.4	12.	0.01	0.99	254.0	28.2	52.	0.04	0.95	249.8	20.1
45 49	5.	0.00	1.00	167.0	24.4	5.	0.00	1.00	245.0	22.8	36.	0.02	0.97	256.3	16.8
50 54	1.	0.00	1.00	165.0	25.0	0.	0.0	1.00	*****	*****	21.	0.01	0.99	256.0	20.3
55 59	1.	0.00	1.00	165.0	23.0	1.	0.00	1.00	260.0	37.0	10.	0.01	1.00	261.5	21.6
60 64	0.	0.0	1.00	*****	*****	0.	0.0	1.00	*****	*****	5.	0.00	1.00	279.0	13.0
65 69	0.	0.0	1.00	*****	*****	0.	0.0	1.00	*****	*****	1.	0.00	1.00	285.0	10.0
70 74	0.	0.0	1.00	*****	*****	0.	0.0	1.00	*****	*****	0.	0.0	1.00	*****	*****
75 79	0.	0.0	1.00	*****	*****	0.	0.0	1.00	*****	*****	0.	0.0	1.00	*****	*****
80 84	0.	0.0	1.00	*****	*****	0.	0.0	1.00	*****	*****	0.	0.0	1.00	*****	*****
85 89	0.	0.0	1.00	*****	*****	0.	0.0	1.00	*****	*****	0.	0.0	1.00	*****	*****
90 94	0.	0.0	1.00	*****	*****	0.	0.0	1.00	*****	*****	0.	0.0	1.00	*****	*****
95 99	0.	0.0	1.00	*****	*****	0.	0.0	1.00	*****	*****	0.	0.0	1.00	*****	*****
100 104	0.	0.0	1.00	*****	*****	0.	0.0	1.00	*****	*****	0.	0.0	1.00	*****	*****
105 109	0.	0.0	1.00	*****	*****	0.	0.0	1.00	*****	*****	0.	0.0	1.00	*****	*****
110 114	0.	0.0	1.00	*****	*****	0.	0.0	1.00	*****	*****	0.	0.0	1.00	*****	*****
115 119	0.	0.0	1.00	*****	*****	0.	0.0	1.00	*****	*****	0.	0.0	1.00	*****	*****

C. Tabulation by wind azimuth classes, showing number of hours (N), frequency (%), cumulative frequency ($\int$%), mean wind speed, and mean air temperature, for each class. Azimuth is expressed in degrees clockwise from True North; 360° must be subtracted from values greater than 360°.

Wind Azimuth [°wrt TN]	CANYON					GULCH					SUMMIT				
	N	%	$\int$%	Speed mph	Temp. °F	N	%	$\int$%	Speed mph	Temp. °F	N	%	$\int$%	Speed mph	Temp. °F
90 104	28.	0.01	0.01	7.1	30.3	11.	0.01	0.01	5.5	23.8	42.	0.03	0.03	7.4	15.4
105 119	0.	0.0	0.01	*****	*****	0.	0.0	0.01	*****	*****	12.	0.01	0.04	8.1	14.8
120 134	34.	0.01	0.03	13.8	36.2	1.	0.00	0.02	4.0	23.0	1.	0.00	0.04	2.0	47.0
135 149	70.	0.03	0.05	17.8	45.1	0.	0.0	0.02	*****	*****	0.	0.0	0.04	*****	*****
150 164	385.	0.16	0.21	19.4	45.6	3.	0.00	0.02	4.3	6.3	2.	0.00	0.04	5.0	15.5
165 179	238.	0.10	0.31	22.6	37.3	3.	0.00	0.02	5.0	0.0	1.	0.00	0.04	4.0	20.0
180 194	457.	0.19	0.49	19.8	36.7	17.	0.02	0.05	4.5	-3.5	15.	0.01	0.05	7.4	20.1
195 209	111.	0.05	0.54	18.0	35.1	1.	0.00	0.05	19.0	12.0	2.	0.00	0.05	5.5	34.5
210 224	173.	0.07	0.61	15.7	29.4	17.	0.02	0.07	7.5	9.6	42.	0.03	0.08	22.6	25.5
225 239	151.	0.06	0.67	15.4	24.3	46.	0.06	0.13	17.6	11.2	423.	0.29	0.38	22.8	26.2
240 254	48.	0.02	0.69	12.7	17.3	247.	0.32	0.45	17.9	15.8	87.	0.06	0.44	15.2	22.3
255 269	5.	0.00	0.69	10.6	40.8	199.	0.26	0.72	19.9	24.1	320.	0.22	0.66	31.5	14.4
270 284	12.	0.00	0.70	3.3	39.0	89.	0.12	0.83	19.5	30.7	139.	0.10	0.76	16.2	19.3
285 299	2.	0.00	0.70	1.5	14.5	0.	0.0	0.83	*****	*****	44.	0.03	0.79	25.6	7.3
300 314	15.	0.01	0.70	2.7	27.5	0.	0.0	0.83	*****	*****	17.	0.01	0.80	4.8	11.6
315 329	1.	0.00	0.70	1.0	37.0	0.	0.0	0.83	*****	*****	1.	0.00	0.80	5.0	12.0
330 344	8.	0.00	0.71	1.8	29.4	0.	0.0	0.83	*****	*****	1.	0.00	0.80	5.0	17.0
345 359	6.	0.00	0.71	1.3	26.8	1.	0.00	0.83	2.0	23.0	27.	0.02	0.82	3.3	10.6
360 374	73.	0.03	0.74	3.1	25.7	1.	0.00	0.83	17.0	12.0	13.	0.01	0.83	5.3	17.2
375 389	11.	0.00	0.74	3.6	22.4	0.	0.0	0.83	*****	*****	3.	0.00	0.83	9.7	17.3
390 404	157.	0.06	0.81	6.4	30.5	0.	0.0	0.83	*****	*****	80.	0.06	0.88	14.6	23.4
405 419	325.	0.13	0.94	6.8	11.9	19.	0.02	0.86	6.8	3.6	64.	0.04	0.93	8.8	22.4
420 434	150.	0.06	1.00	6.4	9.3	73.	0.10	0.96	6.1	0.5	87.	0.06	0.99	10.3	18.4
435 449	3.	0.00	1.00	6.0	34.3	34.	0.04	1.00	8.4	-3.6	15.	0.01	1.00	8.7	16.1

D. Tabulation by air temperature classes, showing number of hours (N), frequency (%), cumulative frequency ($\int$%), mean azimuth (in degrees clockwise from True North), and mean windspeed, for each class. 360° must be subtracted from azimuth values greater than 360°.

Air Temperature °F	CANYON					GULCH					SUMMIT				
	N	%	$\int$%	Azimuth	Speed mph	N	%	$\int$%	Azimuth	Speed mph	N	%	$\int$%	Azimuth	Speed mph
-40 -36	0.	0.0	0.0	*****	*****	0.	0.0	0.0	*****	*****	0.	0.0	0.0	*****	*****
-35 -31	0.	0.0	0.0	*****	*****	0.	0.0	0.0	*****	*****	0.	0.0	0.0	*****	*****
-30 -26	0.	0.0	0.0	*****	*****	42.	0.04	0.04	377.0	4.0	0.	0.0	0.0	*****	*****
-25 -21	50.	0.02	0.02	414.0	6.7	11.	0.01	0.05	423.2	5.5	7.	0.00	0.00	400.0	4.6
-20 -16	38.	0.01	0.03	402.3	4.9	19.	0.02	0.07	280.3	6.9	10.	0.01	0.01	317.0	6.2
-15 -11	22.	0.01	0.04	407.9	6.0	16.	0.01	0.08	289.7	7.8	8.	0.01	0.02	277.5	6.3
-10 -6	67.	0.02	0.06	352.9	8.5	15.	0.01	0.09	320.3	8.7	4.	0.00	0.02	262.5	7.0
-5 -1	47.	0.02	0.08	347.3	7.0	3.	0.00	0.10	223.3	10.0	13.	0.01	0.03	272.7	19.0
0 4	54.	0.02	0.10	328.8	10.0	53.	0.05	0.14	282.8	18.1	68.	0.05	0.07	258.8	21.9
5 9	36.	0.01	0.11	387.6	6.6	43.	0.04	0.18	250.5	18.4	137.	0.09	0.17	257.5	19.6
10 14	69.	0.03	0.14	299.1	9.0	71.	0.06	0.25	250.6	20.2	172.	0.12	0.28	299.0	14.7
15 19	164.	0.06	0.20	262.0	14.1	101.	0.09	0.34	281.4	16.8	240.	0.16	0.45	281.7	20.2
20 24	254.	0.09	0.29	278.6	11.1	129.	0.12	0.46	261.9	15.1	265.	0.18	0.63	270.4	21.4
25 29	351.	0.13	0.42	245.8	12.6	137.	0.12	0.58	254.8	19.8	215.	0.15	0.77	251.8	22.1
30 34	331.	0.12	0.54	236.4	14.7	79.	0.07	0.65	254.4	16.2	197.	0.13	0.91	252.6	21.4
35 39	302.	0.11	0.65	219.3	17.2	130.	0.12	0.77	256.7	17.7	81.	0.05	0.96	256.6	19.8
40 44	306.	0.11	0.76	225.9	18.0	174.	0.16	0.93	239.5	17.0	41.	0.03	0.99	306.3	16.2
45 49	277.	0.10	0.86	193.6	16.6	39.	0.04	0.97	321.0	17.8	15.	0.01	1.00	356.0	16.1
50 54	208.	0.08	0.94	179.0	16.4	19.	0.02	0.98	330.0	18.8	0.	0.0	1.00	*****	*****
55 59	111.	0.04	0.98	191.0	16.2	17.	0.02	1.00	420.0	17.9	0.	0.0	1.00	*****	*****
60 64	43.	0.02	0.99	210.8	16.1	0.	0.0	1.00	*****	*****	0.	0.0	1.00	*****	*****
65 69	14.	0.01	1.00	204.3	16.1	0.	0.0	1.00	*****	*****	0.	0.0	1.00	*****	*****
70 74	0.	0.0	1.00	*****	*****	0.	0.0	1.00	*****	*****	0.	0.0	1.00	*****	*****
75 79	0.	0.0	1.00	*****	*****	0.	0.0	1.00	*****	*****	1.	0.00	1.00	225.0	17.0